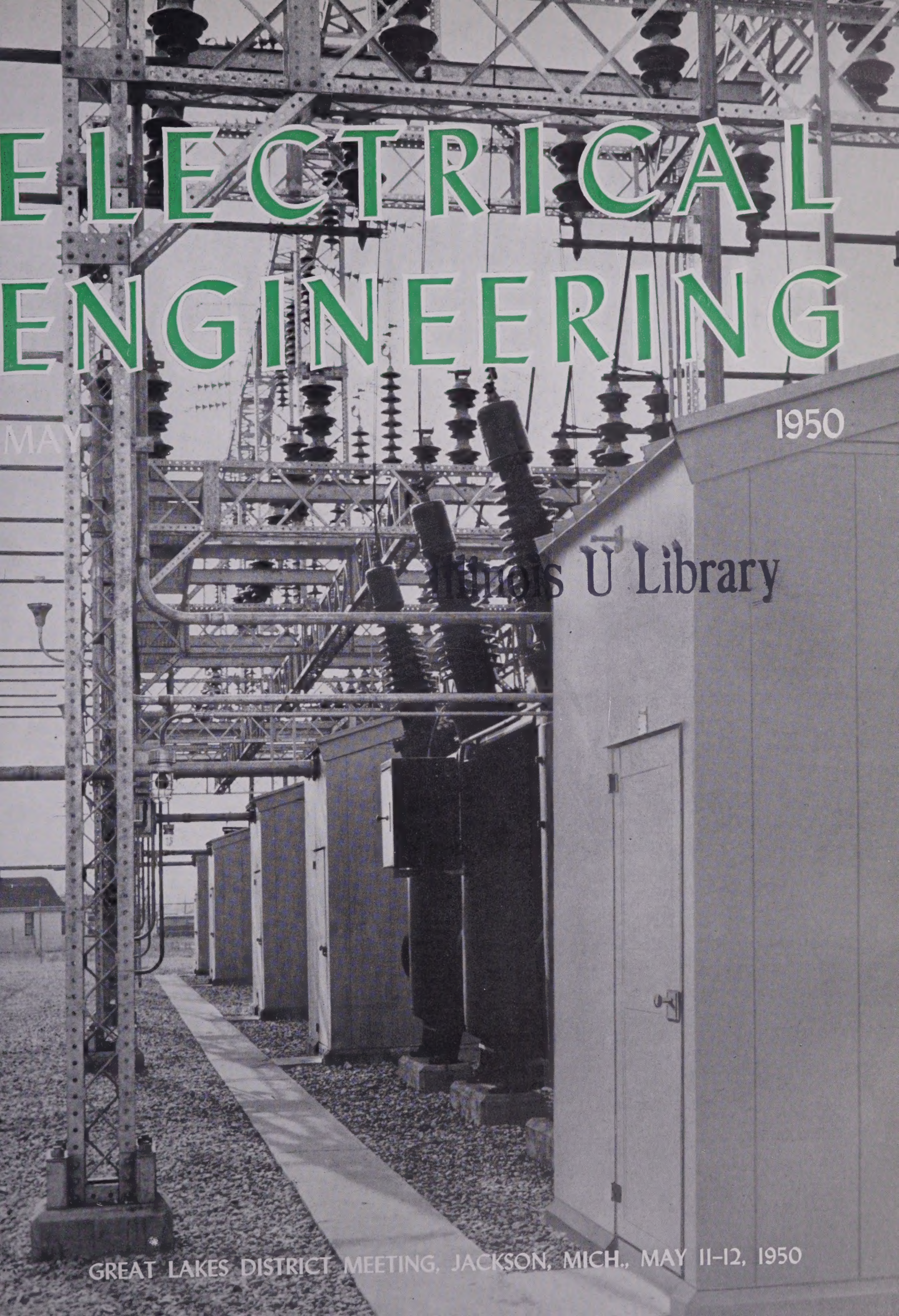
ELECTRICAL ENGINEERING

MAY 1950



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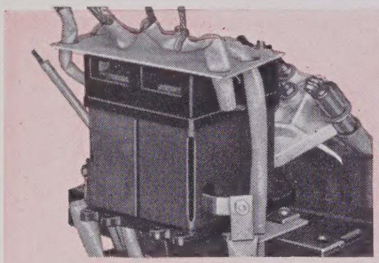

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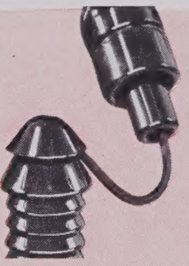

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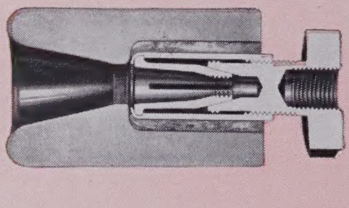

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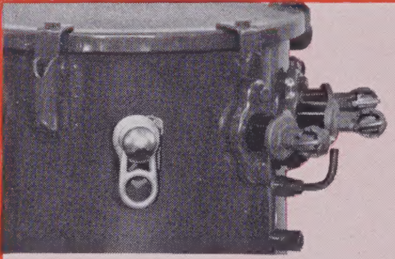

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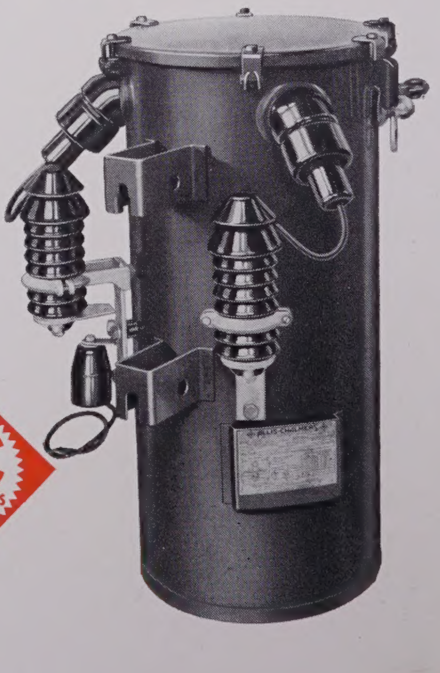

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1950

The Cover: Verona Transmission Substation at Battle Creek, Mich., on the Consumers Power Company system. This substation is scheduled for inspection during the AIEE Great Lakes District Meeting in Jackson.

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VOL. 69 NO. 5

Statements and opinions given in articles appearing in *ELECTRICAL ENGINEERING* are expressions of contributors, for which the Institute assumes no responsibility. Correspondence is invited on controversial matters. Published monthly by the

AMERICAN INSTITUTE OF ELECTRICAL ENGINEERS

Founded 1884

Headquarters
33 West 39th Street
New York 18, N. Y.

Editorial Offices
500 Fifth Avenue
New York 18, N. Y.

JAMES F. FAIRMAN, President
H. H. HENLINE, Secretary

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ELECTRICAL ENGINEERING: Copyright 1950 by the American Institute of Electrical Engineers; printed in the United States of America; indexed annually by the AIEE, weekly and annually by *Engineering Index*, and monthly by *Industrial Arts Index;* abstracted monthly by *Science Abstracts* (London). Address changes must be received at AIEE headquarters, 33 West 39th Street, New York 18, N. Y., by the first of the month to be effective with the succeeding issue. Copies undelivered because of incorrect address cannot be replaced without charge.

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HIGHLIGHTS........

The Student Membership. Marking the 25th anniversary of the Institute's first Student Branch Conference, Chairman Roubik of the Illinois Institute of Technology Student Branch reports one of his Branch's latest activities (*page 388*), while Professor Seeley of Duke University evaluates the first quarter-century of AIEE Student membership activities (*page 389*). "Congratulations, where due," says President Fairman in his introductory article. He goes on to urge us again to express our opinion on Institute policy by making use of the return postal card included in the March issue (*page 387*).

A New Electrical Engineering Building. The story of the new Electrical Engineering Building at the University of Washington is told in this issue with description and pictures. The new building, functional in design, contains laboratories, research rooms, classrooms, and offices for staff members, in addition to a library and study room, a staff conference room, and a student activities room (*pages 434–6*).

1950 Employment Programs. Results of the latest survey of employment programs for engineering graduates indicate that the young engineer would do well to seek his opportunity in the smaller industries. The current report also covers graduates in physical science (*pages 399–404*).

Lightning Arresters and Transformer Insulation. The value of lightning arresters to transformers subjected to high voltages with steep wave fronts is demonstrated in an article by F. J. Vogel of the Illinois Institute of Technology. The results of a series of impulse tests show the effect of these lightning arresters on the insulation which is needed in the transformer (*pages 453–5*).

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Fascimile Telegraph Apparatus. A description of fascimile concentrator apparatus and telefax equipment which has been installed recently in eight large American cities is described in this issue. The article, by three Western Union employees, gives a verbal picture of the apparatus and a complete description of the operating procedure used (*pages 406–08*).

Safety in Substation Design. Unsafe act+unsafe condition=accident. This fatal formula finds frequent application in faultily designed substations. Oddly enough, death by electrocution comes most often to personnel having the greatest experience and information. In this article, the authors discuss the cause and cure of substation accidents (*pages 412–15*).

Tube Voltage Drop in Hot-Cathode Gas Tubes. For users of large quantities of gas-filled electron tubes for industrial control purposes, the failure of a tube can result in costly shutdowns. To prevent this, a series of tests has been developed to predict the end of life of these tubes so they can be removed before failure (*pages 419–22*).

Relay Protection of Transmission Lines. This month the third article of the series on the relay protection of transmission lines presents the system of protection for long, heavily-loaded lines. As well as being able to withstand heavy emergency loads, this protection must provide positive fault protection with allowance for arc impedance, withstand swings inherent with high-speed reclosing, and provide some backup protection (*pages 422–5*).

Rectifier-Type Power for Railroads. In order to make use of the qualities of alternating current for power transmission as well as take advantage of the d-c traction motor, rectifier motive power units are being used for railroad electrification. This gives a simple, flexible means of voltage control while allowing high accelerating horsepowers at high speed and gives minimum accelerating losses, minimum peak power demand, and a large number of running speeds (*pages 439–42*).

Electrically-Driven Gyroscopes. Gerard P. deWestfelt of the Sperry Gyroscope Company tells of the problems introduced in the design of electric motors when those motors are to be used in gyroscopes. The high momentum and mass stability required necessitate radical changes in both the electrical and mechanical designs. High operating speed must be maintained although no cooling other than radial can be provided (*pages 446–51*).

AIEE Proceedings

Order forms for current AIEE *Proceedings* have been published in *Electrical Engineering* as listed below. Each section of AIEE *Proceedings* contains the full, formal text of a technical program paper, including discussion, if any, as it will appear in the annual volume of AIEE *Transactions.*

AIEE *Proceedings* are an interim membership service, issued in accordance with the revised publication policy that became effective January 1947 (*EE, Dec '46, pp 567–8; Jan '47, pp 82–3*). They are available to AIEE Student members, Associates, Members, and Fellows only.

All technical papers issued as AIEE *Proceedings* will appear in *Elecrical Engineering* in abbreviated form.

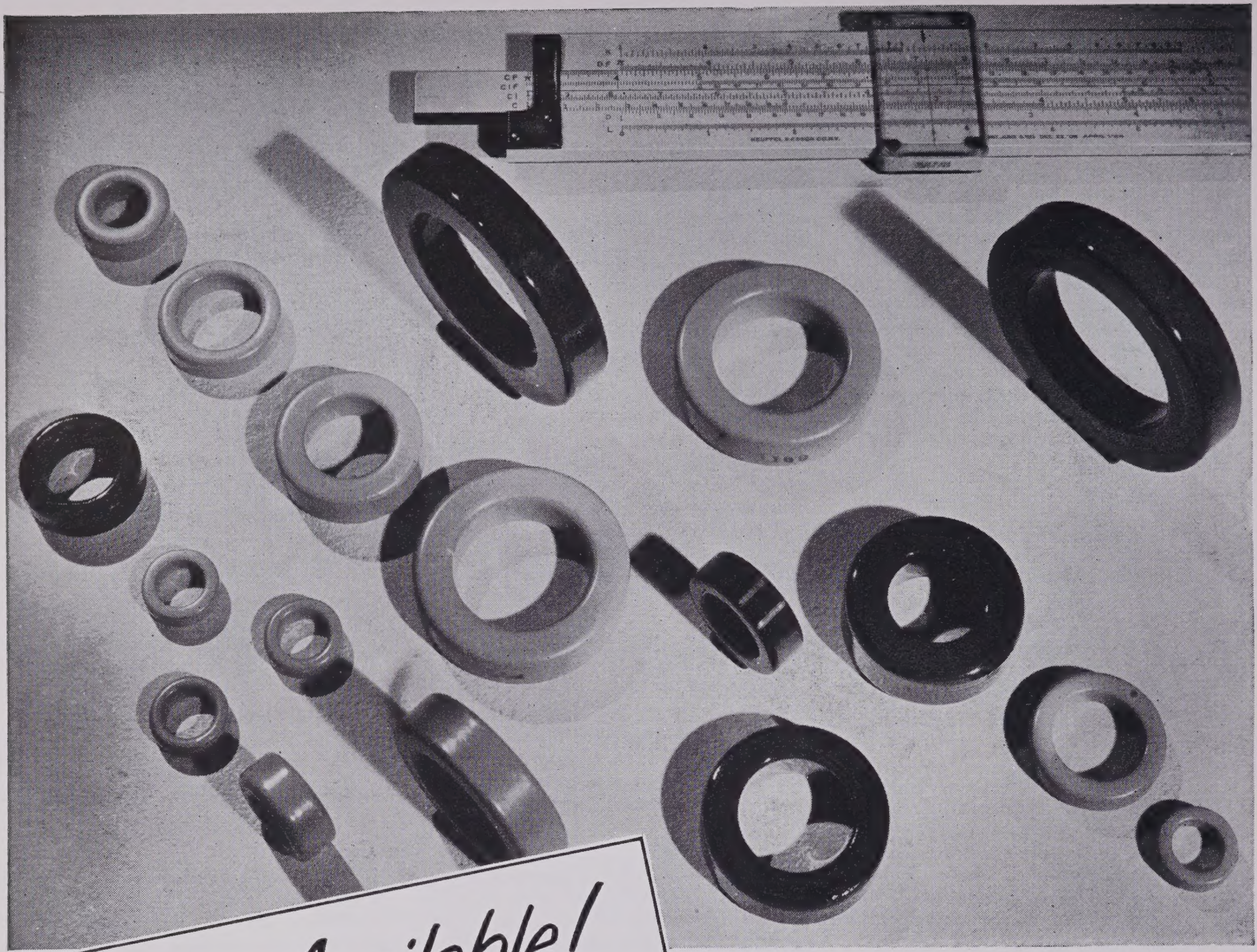
Location of Order Forms	Meetings Covered
Dec '48, p 35A	Midwest General Southern District
Apr '49, p 25A	Winter General (1949)
Jul '49, p 47A	South West District Summer General
Nov '49, p 51A	Pacific General Fall General
Feb '50, p 46A	Winter General (1950)

Regulation of A-C Generators. Included in an article describing the method of calculation of the voltage regulation of a-c generators with suddenly applied loads are two pages of voltage-drop curves. One set is the voltage-drop curves for generators with separately-excited exciters, and the other set is for generators with self-excited exciters. With these curves the regulation of a-c generators when a heavy load is applied suddenly can be calculated (*pages 391–5*).

Vibration Pressure Hypothesis. A mathematical hypothesis is presented which proposes that the cause of electrostatic repulsion is some form of radiation. By considering equations for electrostatic repulsion and for sound radiation the basis for the theory is easily seen. This is used to explain the action which produces force at a distance from itself (*pages 397–8*).

Automatic Recording of Electrical Quantities. Legible and accurate records of any continuous flow process are made with the Metrotype measuring system. The machine selects in sequence the quantities to be measured, makes the measurement, transmits the readings as far as desired, and records them in tabulated numerical form. Capable of measuring and recording a 3-digit reading in 0.8 second, it combines the electronic computer technique with that of the printing telegraph (*pages 427–30*).

ELECTRICAL ENGINEERING. Published monthly by the American Institute of Electrical Engineers; publication office 20th & Northampton Streets, Easton, Pa. Editorial and advertising offices, 500 Fifth Avenue, New York 18, N. Y. Subscription $12 per year plus extra postage charge to all countries to which the second-class postage rate does not apply; single copy $1.50. Entered as second-class matter at the Post Office, Easton, Pa., under the Act of Congress of March 3, 1879. Accepted for mailing at special postage rates provided for in Section 538, P. L. & R. Act of February 28, 1925. May 1950, Vol. 69, No. 5. Number of copies of this issue 53,500



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The President Says—

Happy Birthday!

If it had not been for Professor Walter J. Seeley, Vice-President of District 4, we should have missed this one. At the last meeting of the Board of Directors on February 2, he called our attention to the fact that the first Student Branch Conference of the Institute was held 25 years ago this spring under the joint auspices of the Philadelphia Section and the Student Branch at the University of Pennsylvania. He reminded us of the results of that first conference and urged some appropriate observance of its 25th anniversary. As usually happens to the maker of a good suggestion, he was given the job of writing the story. It is a story by an eyewitness. He was Chairman of the Student Branch Committee of the Philadelphia Section at the time. Our thanks to him for the reminder and for preparing the article. (See page 389.)

Those who had the major part in organizing that first Student Branch Conference are named in Professor Seeley's article. To them and to their associates our everlasting appreciation for their interest, initiative, and foresight. They started something of incalculable value to the succeeding generations of students and to the Institute as well. Also, our congratulations to the Philadelphia Section and to the University of Pennsylvania Branch upon their sponsorship of this successful enterprise.

Congratulations!

Congratulations to the Student Branch at the Illinois Institute of Technology upon the program they initiated in 1948 (see page 388), a year in advance of the suggestion I made in my address at the 1949 Fall General Meeting in Cincinnati. I wish that I might have known about it at the time so that I could have used it as an example.

Thanks to Professor Eric Gross for calling it to your editor's attention and to Frank R. Roubik, Chairman of the Branch, for his excellent article.

How many other lights are hidden under bushels? Let's have more reports from the grass roots. Who knows when experiments of this kind will lead to broadly beneficial results similar to that of the Philadelphia story cited.

Let's Finish the Job

I refer, of course, to the second opinion poll as presented in the March 1950 *Electrical Engineering*, pages 191–4. As of the time this goes to press, the returns are disappointing in number, less than one-third of the number received from the first poll taken last fall. Surely all who expressed an opinion the first time should be willing to take advantage of this opportunity to affirm their original verdict or to change it if they so desire in the light of a better understanding of the problem. Surely many of those who overlooked the earlier poll will want their views to influence the course we shall choose for the future. Surely all will agree that your Board of Directors can proceed with more confidence that they are carrying out policies approved by the membership if a substantial majority of the total membership indicates its opinion as to each of the three propositions on the postal card.

To afford everyone an opportunity to have his opinion taken into account, the deadline has been extended to May 15. *Dust off the March issue, turn to page 193, detach, mark, and mail that postal card. Do it now.*

At many Section meetings, I have been asked: "What does the Institute think?" I have always replied: "That is what we are trying to find out. You are the Institute. What do you think?"

The results will be published by Sections and by Districts as before. Each of us will want his Section to make a good showing of interest. It's up to each of us, isn't it? Let's show the students that we old fellows are alive too.

And yes, the students can express their opinion. It will be their Institute in a very few years. We need to know what they think. Students should indicate that fact by putting the name of the Branch on the line for the Section.

Let's have a little healthy competition.

Last Call for Your Opinion on Institute Policy

James F. Fairman, President AIEE, is Vice-President, Consolidated Edison Company of New York, Inc., New York, N. Y.

Report From the Grass Roots

FRANK R. ROUBIK
STUDENT MEMBER AIEE

IN RECENT YEARS, engineering students have been constantly reminded that, in addition to their technical abilities, they must acquire and maintain poise, understanding, and a co-operative spirit in their daily associations with other people.

This "getting along with people" requirement seemed perfectly logical and was accepted by most of the students, but the young engineers were not satisfied. What was to serve as a reference, a guide to proper human relations? Assuredly, many books and articles had been written about the importance of the co-operative attitude in industry, and many authors had presented as many of the unwritten yet observable laws of industry as they could recall from their personal past experiences.* From these works, the industrious student could surely establish a plane of reference for the proper industrial social conduct.

During the fall term of 1948, the AIEE Student Branch at the Illinois Institute of Technology in Chicago, under its Chairman, James H. Kogen, decided to augment the available material by a series of lectures dealing with these highly important topics. This was an entirely new field for the Branch, but with a national organization of practicing engineers as potential lecturers the program was slated for success.

As a broad over-all topic for the lecture series, the Branch selected: "What Does Industry Expect of the Junior Engineer, and What Can the Junior Engineer Expect in Return?" Aided by the Students and Young Engineers Committee of the AIEE Chicago Section and Counselor Dr. Eric T. B. Gross, the program of presenting lecturers who could inform the 340 Branch members about the human side, the ever-evasive, ever-changing aspects of the engineering profession, was inaugurated.

The Chairman of the Chicago Section at that time, F. D. Troxel, Chief Electrical Engineer, Vern E. Alden Company, Consulting Engineers, presented the first lecture of the series entitled, "Opportunities in Engineering." In his presentation, he warned the students that regardless of their technical training and proficiency, they would always be in a position of soliciting co-operation from other people. In order to clarify his statements, he discussed several basic human engineering problems observed while with the Manhattan Project.

During the early winter of 1948, the Illinois Law for Professional Engineers was receiving much attention and the Branch was most fortunate in obtaining Titus LeClair, Assistant Chief Electrical Engineer of Commonwealth Edison Company, Chicago, as the second guest lecturer; he discussed "The Laws for Professional Engineers and How They Affect the Student."

These gentlemen were only the vanguard of a long list of prominent engineers that the Student Branch was fortunate in obtaining. Guest lecturers included: E. J. Howard, Supervisor of College Employment for Illinois Bell Telephone Company; Alex D. Bailey, Vice-President in charge of Operations, Commonwealth Edison Company, Chicago: Francis A. Cox, Assistant Electrical Engineer, Public Service Company of Northern Illinois; Edwin W. Seeger, Vice-President in charge of Development, Cutler-Hammer Inc., Milwaukee, Wis.; Frank V. Smith, Chief Electrical Engineer, Sargent and Lundy, Engineers; P. A. Abetti, Research Engineer, General Electric Company, Pittsfield, Mass.; G. B. West, Chief Engineer, Illinois Bell Telephone Company; P. B. Garrett, Editor, *Electric Light and Power*, Chicago. All these men presented their views on the problems which a junior electrical engineer encounters in industry. Their formal presentations were supplemented by anecdotes of personal experiences, the value of which will certainly be realized by the Student members in the years to come.

As an example of how the question was treated, Mr. Smith divided the electrical engineering profession into various categories and then listed the temperaments and traits needed for each established category. Dr. Abetti presented the topic, "How Collective Genius Contributes to Industrial Progress," which indicated quite clearly how the co-operative attitude is needed in the operation of modern industrial organizations.

As for the future, this Student Branch will continue to present the special series of lectures dealing with the human aspects of engineering, in addition to its regular technical meetings and to field trips to manufacturing and power plants in the Chicago area. Also included in the Branch activities is the annual undergraduate and graduate students Papers Contest and the Young Engineers Night, both sponsored by the AIEE Chicago Section, which provide ample opportunity for the students to meet many of their fellow members and also practicing engineers. Thus, through actual participation the students learn the vital role that human relations play in engineering.

From the men in industry, the Branch members at the Illinois Institute of Technology have heard, questioned, and learned much about the unwritten laws of engineering. If industry continues to co-operate with the Student Branches by providing a beforehand account of some of the nontechnical pitfalls the junior electrical engineer will encounter, Mr. Fairman and all AIEE members can be quite certain that the "grass roots" of the coming engineering generation will be most firmly planted in the best of all soils, *understanding*.

Frank R. Roubik is Chairman (1949–50) of the AIEE Student Branch at the Illinois Institute of Technology, Chicago, Ill.

* See, for example, an excellent brochure available for 50 cents from the Bookstore of Northwestern University, Evanston, Ill., entitled: "On Views and Guides for the Electrical Engineer," by J. F. Calvert and W. J. King.

A Quarter Century of Student Branch Conference Activity

W. J. SEELEY
FELLOW AIEE

JUST 25 years ago the first Student Branch Conference of the AIEE met at the University of Pennsylvania in Philadelphia. It was then called a Student Branch Convention and was a joint activity of the Philadelphia Section and the Student Branch at the Moore School of Electrical Engineering. The following account of that meeting is quoted from the April 1925 AIEE *Journal*:

> An innovation for the Institute, a Student Branch convention, was held on March 9 at the Moore School of Electrical Engineering, University of Pennsylvania, under the direction of the Philadelphia Section. Students from nine colleges and others attended the meeting making a registration of about 300. The meeting lasted one day and consisted of technical papers by students in the morning, inspection trips in the afternoon, and dinner and an address by President Farley Osgood in the evening.
>
> This meeting was entirely worth while to the students and to the Institute. It increased the students' interest in AIEE affairs and gave them an excellent opportunity to meet the electrical students from the other colleges. Those responsible for the arrangements deserve high commendation. The technical session consisted of:
>
> "The Small College in Engineering Education," by John B. Donal, Swarthmore College
>
> "A Voltage Survey," by F. J. Berger, Lehigh University
>
> "Radiobroadcasting at Haverford College," by Winthrop M. Leeds and Gerald C. Gross, both of Haverford College
>
> "The Oil-Electric Locomotive," by J. B. Powell and C. L. Craven, both of Lafayette College
>
> Three inspection trips were made in the afternoon. These were to Delaware Station of the Philadelphia Electric Company, Parkway Building of the Bell Telephone Company of Pennsylvania, and Villanova, Haverford, and Swarthmore Colleges.
>
> After the dinner in the evening, President Farley Osgood spoke on "What a College Man Goes Up Against and How to Meet It." He gave a very inspiring talk outlining some of the problems which the engineering graduate has to face and giving some very wholesome practical advice on overcoming these problems.
>
> The colleges participating in the convention were Drexel Institute, Haverford College, Lafayette College, Lehigh University, Princeton University, Swarthmore College, University of Delaware, University of Pennsylvania, and Villanova College. Special credit for planning and conducting the meeting must be given to the officers of the Philadelphia Section, the officers of the Student Branch at Moore School of Electrical Engineering, and the Student Branch Activities Committee, consisting of professors and other engineers in the territory represented.

It is interesting to follow the careers of the six young men who participated in that original meeting to see where they are today. Thus, from the 1949 AIEE Yearbook:

Berger, Francis Joseph (A '27, M '44), Inside Plant Engineer, Electrical Engineering Division, Philadelphia Electric Company, 900 Sansom Street, Philadelphia 5, Pa.; for mail, 528 Elm Avenue, Upper Darby, Pa.

Craven, Claude L. (M '40), Senior Staff Engineer, Bell Telephone Company of Pennsylvania, 1835 Arch Street, Philadelphia 3, Pa.; for mail, 517 Midvale Avenue, Philadelphia 44, Pa.

Gross, Gerald Connop (M '42), Assistant Secretary General, International Telecommunication Union; for mail, c/o American Legation, Berne, Switzerland

Leeds, Winthrop Moorhead (A '32, M '38, F '48), Manager, Circuit Breaker Development Section, Power Circuit Breaker Engineering Department, Westinghouse Electric Corporation, East Pittsburgh, Pa.

Powell, John B. (A '29, M '43), Engineer, Apparatus Department, General Electric Company, 129 Church Street, New Haven, Conn.; for mail, 153 Woodlawn Street, Hamden 14, Conn.

Data from the Institute of Radio Engineers 1949 Yearbook:

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The original organizing committee, all but two of whom are still functioning actively in Institute affairs comprised:

Dr. Lewis Fussell, Professor of Electrical Engineering at Swarthmore College, now deceased

Professor L. H. Rittenhouse, of Haverford College, now retired. Member for Life

Professor Morland King, of Lafayette College, now Head of the Electrical Engineering Department; Fellow and Member for Life

O. W. Eshbach, Personnel Director, Bell Telephone Company of Pennsylvania, now Dean of Engineering, Northwestern University; Fellow

W. J. Seeley, Chairman of the Student Branch Committee of the Philadelphia Section, Instructor in the Moore School; now Head of Electrical Engineering Department, Duke University; Fellow and Vice-President

Professor C. D. Fawcett, Chairman of the Philadelphia Section, Student Branch Counselor at Moore School, and over-all chairman of the convention activity; now Professor of Electrical Engineering, Moore School; Member for Life

It is noteworthy that in both groups early interests in the Institute have continued for a quarter century.

The interest aroused by this first Student Branch Conference led Sections and Branches in other parts of the country to follow the example set in the Philadelphia area. In 1926 the District Conference on Student Activities for the general discussion of Branch affairs was inaugurated on a trial basis, and put into effect universally during the following year. In 1947, in accordance with provision from the Member-for-Life Fund, the winners of the best Student paper competition in each odd-numbered District were sent to the Summer Meeting. In the even years those from the even-numbered Districts have been sent.

In 1925, there were 4,700 Students enrolled in 82 Student Branches. Today, there are 19,878 Students enrolled in 130 Student Branches. In 25 years the Philadelphia experiment has attained the status of a major Institute activity, and has been an important factor contributing to the growth and success of the organization.

W. J. Seeley is Head of the Electrical Engineering Department, Duke University, Durham, N. C., and Vice-President, District 4.

Equalization of Coaxial Lines

K. E. GOULD
ASSOCIATE AIEE

EQUALIZATION of coaxial lines for television service involves requirements more severe than those which apply for telephone service. Level variations throughout the transmission band must be smaller for television transmission, and the delay distortion, which presents no serious problem in the broad-band system used for telephone service, must be equalized. This delay distortion within the transmitted band arises primarily from gain cutoff outside the band and thus usually is of a broad nature. The magnitudes, however, are such that a high degree of precision is needed to meet television requirements.

On the Bell System's coaxial lines now in operation, two types of adjustable gain equalizers are employed. One type, designated the *A* equalizer and appearing at each main office, provides adjustments designed to compensate the principal known gain deviations and, in addition, to take care of a wide variety of minor deviations with moderate precision. The other type, known as the *B* equalizer, appears less frequently, and provides loss-frequency shapes which are largely complementary to those incorporated in the *A* equalizer. In combination, the two equalizers provide a rather powerful tool for adjusting the gain throughout the entire band.

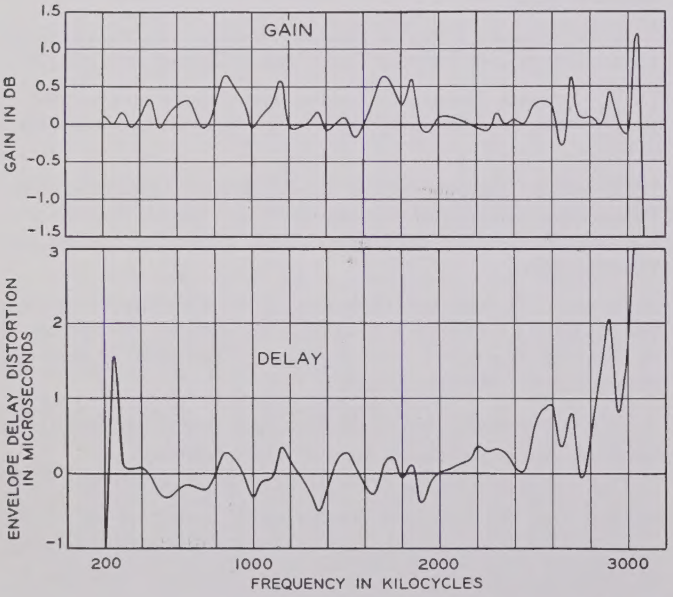

Figure 1. Transmission characteristics of Washington–Chicago circuit

The envelope delay distortion of a coaxial line is of the order of four microseconds per hundred miles at the lower edge of the band and 13 microseconds at the upper end. Delay equalization is provided which increases the delay at other parts of the band to the system delay at the upper edge of the band, with some further increase in the form of a constant delay. The bulk of the delay equalization required for a length of the order of a hundred miles is provided at the transmitting end. A certain amount of adjustable delay equalization is provided to take care of variations in the delay due to such things as temperature effects, vacuum tube aging, and deviations in amplifier performance.

To take care of differences in system layouts, considerable flexibility is required in the delay equalizers available. This has been accomplished by providing a series of "building blocks" of delay equalization beginning with a large unit which will equalize a representative long section between television dropping points and progressing through successively smaller units until the residual interpolation can be made with adjustable units.

Since there are moderate variations in the proportions of auxiliary repeater sections, transmitting and receiving sections and flat gain amplifiers, for each of which the delay distortion characteristic is different, additional flexibility is required in delay equalizers beyond simply a scale-factor change. This is accomplished by incorporating minor changes in the delay-frequency characteristics of some of the smaller units, and more particularly by providing supplementary units which bridge the gaps between the various system layouts, that is, between the various extremes in proportions of the several components which contribute to delay distortion.

The usefulness of adjustable equalizers, both for gain and for delay, obviously depends upon the availability of adequate measuring equipment and test procedures. Point-by-point measurements have been used to date, although automatic recording equipment is under development. Visual indication of the gain-frequency characteristic on a cathode-ray tube has been used successfully on an experimental basis, but further experience with television transmission on coaxial systems will be required before a sound decision can be made on the ultimate gain and delay measuring equipment.

An example of coaxial system equalization for television transmission is shown in Figure 1, which exhibits the measured gain and envelope delay distortion for a circuit from Washington to Chicago. In this connection, it should be noted that the single-sideband television signal has its carrier at about 311 kc and a vestigal sideband extending roughly to 200 kc. Figure 1 is representative of the performance presently obtainable with these facilities, although perhaps not as good as that which might be realized from an installation incorporating recent improvements.

Digest of paper **49-248,** "Equalization of Coaxial Lines," recommended by the AIEE Committee on Communication and approved by the AIEE Technical Program Committee for presentation at the AIEE Fall General Meeting, Cincinnati, Ohio, October 17–21, 1949. Scheduled for publication in AIEE *Transactions,* volume 68, 1949.

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Regulation of A-C Generators With Suddenly Applied Loads

E. L. HARDER R. C. CHEEK J. M. CLAYTON
FELLOW AIEE MEMBER AIEE ASSOCIATE AIEE

When a large motor is added to the load of a relatively small power plant, the effect of the voltage drop on other connected load as well as on that just added must be considered. This article gives curves and methods used in calculating the voltage regulation of generators with suddenly applied loads of relatively large magnitude.

THE determination of the voltage regulation of a-c generators with suddenly applied load has become a problem of considerable importance. When the load which may be added suddenly is appreciable compared with the connected generating capacity, consideration must be given to the effect of the voltage drop on other connected load as well as on that just added. Too great a drop may result in the dropping out of a-c contactors on other equipment, stalling of heavily loaded motors, malfunctioning of radar or other voltage-sensitive equipment, and in adverse effects upon the starting characteristics of motors thrown on the line. Relatively small power plants with large motor loads are particularly subject to this phenomenon since the starting load may be several times the running load. Examples are isolated coast-defense gun installations, naval ship-service generators, industrial power plants, and auxiliary house generators of central-stations. In the latter case a heavy motor load may be transferred to the house generator if the normal supply fails.

The curves presented in this article are the mathematical solution of a basic regulating system whose performance may be expressed as follows: At time zero (Figure 2), a load, or an additional load, is suddenly thrown on the generator, causing a sudden drop in terminal voltage. A definite time, *h*, later a direct voltage is suddenly impressed in the exciter field circuit and starts to build up the exciter field current. In the indirect acting regulator this is accomplished by closure of the quick-response contactor, *Q*, Figure 1. As the exciter builds up, the downward trend of generator voltage is halted at some time, *t*, and the voltage is started upward toward normal.

VOLTAGE-DROP CURVES FOR A-C GENERATORS

The voltage-drop curves for generators with separately excited exciters are given in Figure 3. There are 12 graphs in all, covering four values of exciter response, *R*, from top to bottom, and three values of generator open-circuit time constant, T_{do}' from left to right. Each graph is a family of five curves for different values of generator transient reactance, x_d'. The maximum voltage drop is plotted as ordinate against the suddenly-applied load as abscissa. The applied load is treated as a fixed impedance of low power factor and is expressed, not as the current actually drawn, but in terms of that which would have been drawn with maintained voltage. This current is expressed in per cent of generator rating.

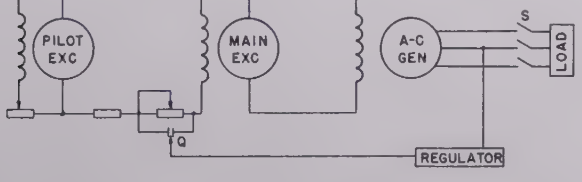

Figure 1. Components of excitation system with indirect-acting regulator and separately-excited exciter

The simplest problem is a direct one. It is to determine the voltage drop that would be caused by a 300-horsepower induction motor starting at reduced voltage of 60 per cent through a starting transformer on a 2,000-kva generator having an open-circuit time constant, T_{do}', of 3.0 seconds, and a transient reactance, x_d', of 20 per cent. The exciter response, *R*, is 1.0, and an indirect acting regulator with quick response contactors is used. The full-voltage starting current of the motor is given as 6.5 times normal and the rated kva as 280.

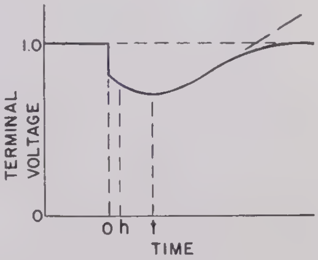

Figure 2. Terminal voltage versus time after a sudden load application at time 0. A direct voltage is applied to exciter field at time h.

At the reduced voltage (assumed maintained) the motor inrush in per cent of generator rating would be

$$\text{Applied load} = \frac{280 \times 6.5 \times (0.60)^2}{2,000} = \frac{656}{2,000} = 32.8 \text{ per cent}$$

In Figure 3, curves are available for a response of 1.0 but it will be necessary to interpolate between $T_{do}' = 2$ and 4.

Essentially full text of paper **50-58**, "Regulation of A-C Generators With Suddenly Applied Loads," recommended by the AIEE Committees on Power Generation and Transmission and Distribution and approved by the AIEE Technical Program Committee for presentation at the AIEE Winter General Meeting, New York, N. Y., January 30–February 3, 1950. Scheduled for publication in AIEE *Transactions*, volume 69, 1950.

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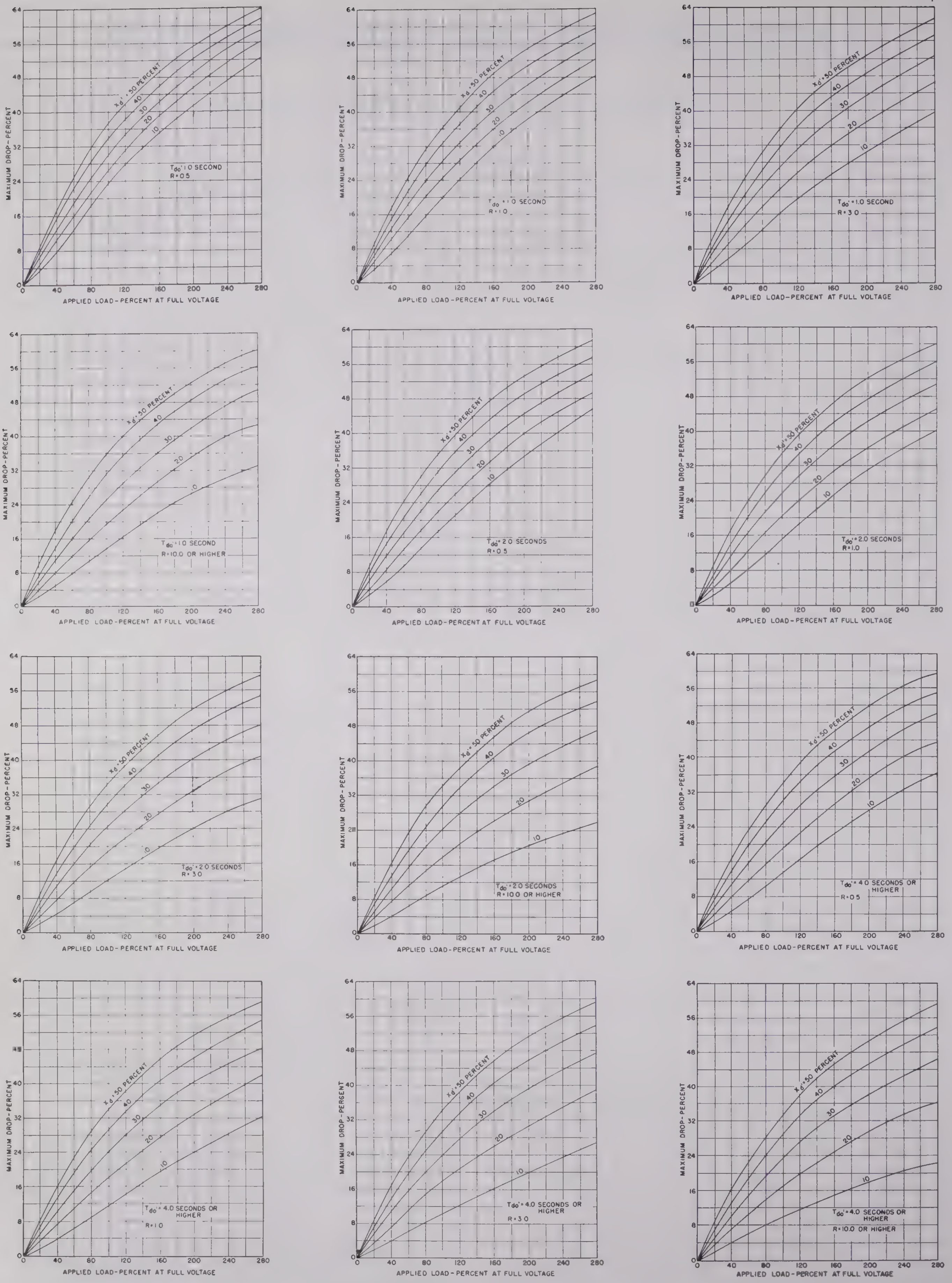

Figure 3. Voltage drop versus suddenly applied load for generators having separately excited exciters and with various transient reactances, x_d', time constants, x_{do}', and nominal exciter responses, R

For $R = 1.0$, $T_{do}' = 2.0$, the voltage drop at 32.8 per cent load is 6.5 per cent as read on the curve for $x_d' = 20$ per cent. For $R = 1.0$ and $T_{do}' = 4.0$, the drop at 32.8 per cent load is 6.4 per cent. These values are the same within the accuracy of the curves. The voltage drop may be taken as 6.5 per cent.

FACTORS INFLUENCING VOLTAGE REGULATION

The maximum voltage drops have been given as functions of the four principal parameters; namely, added load, generator transient reactance, generator time constant, and exciter response. There are a number of other factors entering into the equations for maximum voltage drop, but as has been shown previously,[1] these are generally minor factors, which justifiably can be represented by average values in determining voltage drops.

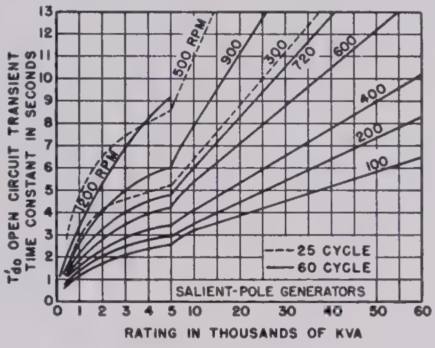

Figure 4A. Typical open-circuit time constants of machines of different speeds

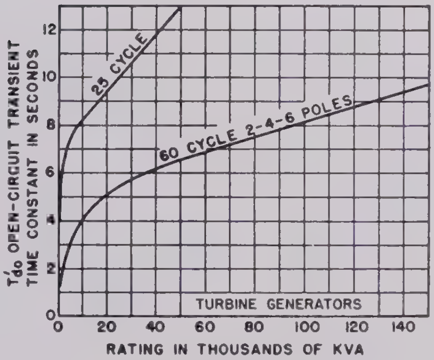

Figure 4B. Typical open-circuit time constants of machines of different frequencies

Typical values of the principal factors affecting voltage drop are given in Table I and Figure 4. In the table the value above the line represents the average of a large number of machines considered and the values below the line give the range. The values of all the minor parameters held constant in the study are given in Table II.

Generator Synchronous Reactance and Short-Circuit Ratio. The maximum voltage drop increases with an increase in synchronous reactance, x_d. With average generator and exciter characteristics, the change in maximum drop at 100 per cent applied load is about two parts in 25 as x_d is varied from 120 per cent down to 100 per cent or up to 140 per cent. With 20-per cent saturation at no load, the corresponding variation in short-circuit ratio is from 1.0 up to 1.2 or down to 0.86. These variations from the average x_d of 120 per cent are as large as are usually encountered among normal machines, and the curves of Figure 3 can be used directly for normal machines without serious error for most purposes.

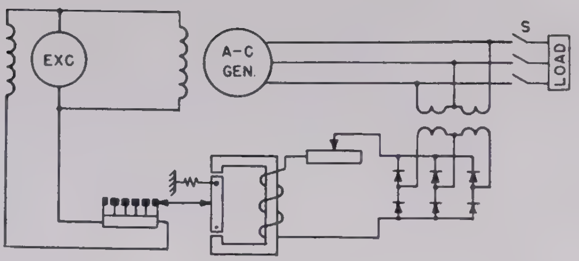

Figure 5. Components of excitation system with direct-acting regulator and self-excited exciter

An accurate figure for maximum voltage drop may be required in some cases where generator synchronous reactance differs greatly from 120 per cent. The curves of Figure 3 can be used for the precise determination of drop in such cases by first expressing generator reactances and the applied load on a new kilovolt-ampere base, such that x_d on the new base is 120 per cent, and then applying the curves. For example, suppose a low-power-factor load of 1,500 kva (expressed at full voltage) is to be applied to a 3,000-kva generator having 30-per cent transient reactance and 150-per cent synchronous reactance. Suppose that the generator time constant is 4.0 seconds and the exciter has a nominal response of 1.0. To determine the drop, express the transient reactance and the applied load on the kilovolt-ampere base upon which x_d is 120 per cent. The base in this case will be $3,000 \times 120/150 = 2,400$ kva. On this base the transient reactance x_d' is $30 \times 2,400/3,000 = 24$ per cent, and the applied load is $1,500/2,400 = 62.5$ per cent. From the curves of Figure 3, the maximum voltage drop is 13 per cent for 62.5-per cent load applied to a generator having 24-per cent transient reactance, a time constant of 4.0 seconds, and an exciter of 1.0 nominal response.

Table I. Typical Values of Principal Factors Affecting Voltage Drop*

	x_d	$x_{d}'_{\text{saturated}}$
Two-pole turbine generators	1.10 0.95–1.45	0.155 0.12–0.21
Four-pole turbine generators	1.10 1.00–1.45	0.23 0.20–0.28
Salient-pole generators	1.15 0.60–1.45	0.37 0.20–0.50
Exciter response		1.0 0.5–3.0

* Reactances are per unit. Values below the line give the range of values, while those above give an average value.

Table II. Summary of Basis of Curves of Figures 3 and 6

Description	Notation	Value
Direct-axis transient reactance	x_d'	1.06 $x_{d}'_{\text{saturated}}$
Direct-axis synchronous reactance	x_d	1.20 per unit
Quadrature-axis synchronous reactance	x_q	0.75 per unit
Excitation for saturation at no load, normal voltage		0.20 per unit
Regulator equivalent operating time		0.05 second
Added load—constant impedance		0.35 power factor
Initial load		Zero
Regulating systems		As shown in Figures 1 and 5

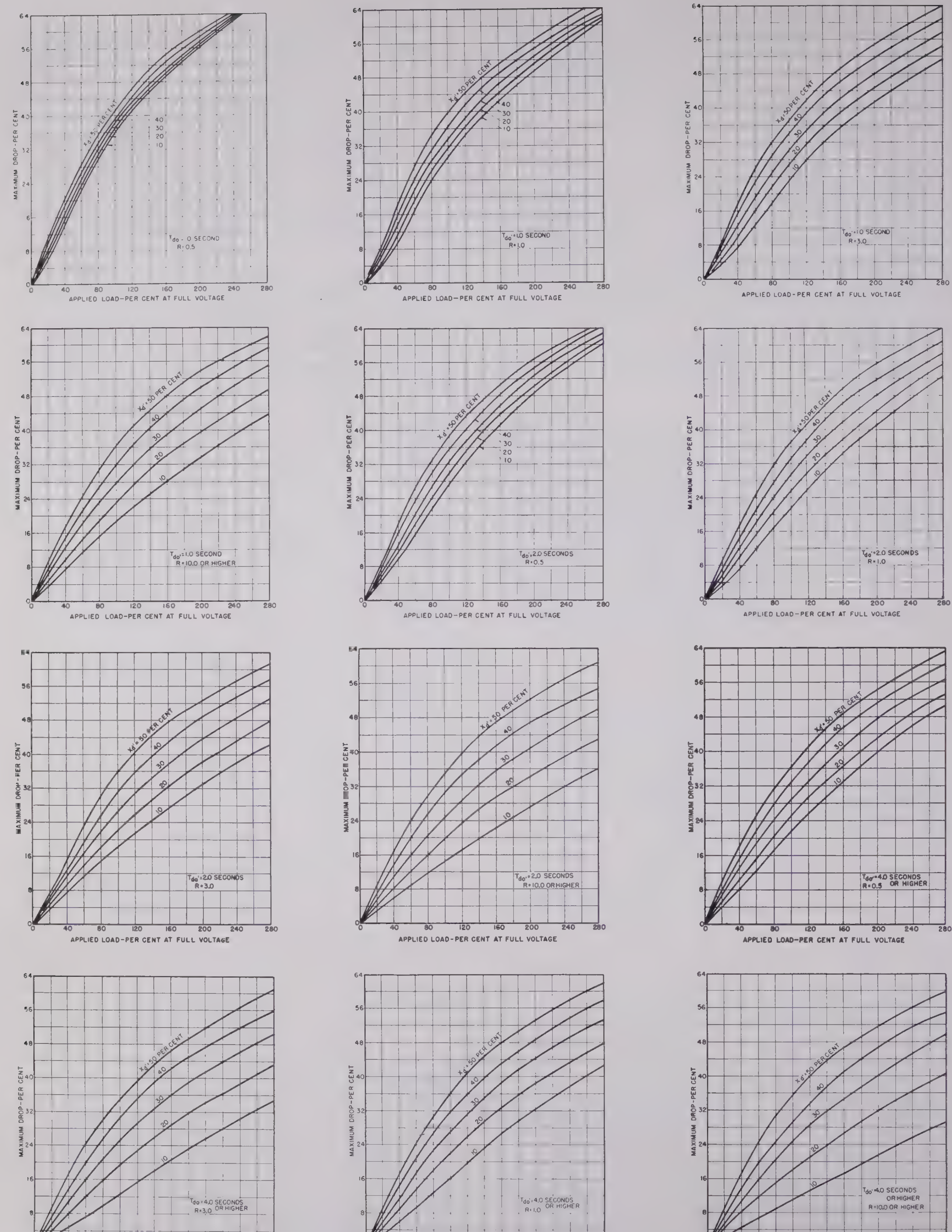

Figure 6. Voltage drop versus suddenly applied load for generators having self-excited exciters and with various transient reactances, x_d', time constants, T_{do}', and nominal exciter responses, R

This same maximum drop would be obtained with the machine and load under consideration.

Generator Open-Circuit Time Constant. This time constant, T_{do}', is the ratio of inductance to resistance of the generator field circuit under unsaturated conditions. The resistance should include all resistance in the field circuit. Typical values for the machine alone are given in Figure 4.

The exciter response, R, is the nominal response as defined by the American Standards Association. It is the average rate of open-circuit exciter voltage increase from nominal voltage during the first half-second after the field resistance is short-circuited expressed in per unit of nominal voltage. Nominal voltage is understood to be that required on the slip rings when the generator is operated at rated voltage, load, and power factor. It is necessary that the response, R, used in estimating voltage drop be based on cutting out the same resistance as is cut out by the quick-response contactors in the actual application.

Regulator Operating Time. The regulator operating time, h, has been taken as three cycles or 0.05 second. The quick-response contactors of indirect-acting regulators are frequently guaranteed to operate within this time for a voltage drop of ten per cent or more. If the transient reactance voltage drop is insufficient to operate the quick-response contacts, the regulator action is comparatively slow and the curves do not apply in this region.

Initial Load. The curves are based on no initial load but apply also if initial load is present. The initial load causes somewhat less drop if the load is static, somewhat more drop if the load is dynamic (running motors), and about the same drop if the load is evenly divided. Thus the no-load case is also typical of an average mixed initial load.

Characteristics of Applied Load. The curves of Figure 3 are based on a constant-impedance applied load, which can be used to represent an induction motor during the starting period. In the curves the power factor of applied load was taken as 35 per cent, a typical motor-starting power factor. The maximum voltage drop is practically the same for all power factors from zero to 40 per cent but decreases rapidly for power factors above this.

The regulating system for generators having self-excited exciters is shown in Figure 5. The voltage-drop curves for this regulating system are included in Figure 6.

CONCLUSIONS

As a result of the studies described in this article and previous studies,[1] the following conclusions have been reached regarding the importance of factors affecting voltage drop with suddenly-applied low-power-factor load:

1. The maximum voltage drop accompanying suddenly-applied low-power-factor load can be expressed in terms of four main parameters for generators with self-excited exciters and separately-excited exciters.

2. In the generator, the transient reactance and the open-circuit time constant are of prime importance. Reasonable variations in synchronous reactance have less effect. A method is presented for correcting for wide variations in synchronous reactance when using the voltage-drop curves; this method applies to generators with self-excited or separately-excited exciters. Variations in quadrature reactance and saturation have practically no effect on maximum voltage drops.

3. For self-excited and separately-excited exciters, the nominal response adequately expresses for practical cases the effect of exciter characteristics upon maximum voltage drops.

4. The regulator operating time, initial load, and variations in the power factor of the applied load from 0 to 40 per cent have negligible effect on the maximum voltage drop.

REFERENCE

1. Regulation of A-C Generators With Suddenly Applied Loads, **E. L. Harder, R. C. Cheek.** AIEE *Transactions*, volume 63, 1944, pages 310–18.

New Discovery in Low-Temperature Physics

Settled at last is a 9-year-old controversy over the energy content of Helium II, that intriguing liquid which flows up the walls of a containing vessel in seeming defiance of gravity and issues without friction through virtually vacuum-tight openings.

The dispute originated in this manner: Scientists discovered that Helium II, a substance which comes into existence at 2.19 degrees Kelvin (liquefaction point of ordinary helium is 4.2 degrees Kelvin), has two constituents, a normal fluid and a superfluid. It is the superfluid which is responsible for the strange behavior of Helium II.

Two theories were devised to explain the unusual physical properties of the superfluid. L. Tisza in 1940 postulated that the atoms of this substance contain a small amount of thermal energy. The following year, L. Landau stated that superfluid atoms possess absolutely no thermal energy.

There was a way to solve the dilemma, however. Both men predicted the existence in Helium II of a heat-propagating phenomenon known as "second sound," so called because heat was expected to travel through the liquid in a manner resembling sound. Each agreed in their estimation of second-sound velocity from 2.19 degrees down to 1.3 degrees. At the latter temperature, there was a divergence of opinion. Decreasing temperatures will increase the velocity, stated Landau. Tisza maintained that further cooling would decrease second-sound velocity.

Thus, the question of superfluid energy content could be solved by measuring the speed of the sound-like heat waves at temperatures below 1.3 degrees. This is what two National Bureau of Standards men, J. R. Pellam and R. B. Scott, have done. They have found that the velocity of second sound rises from 60.4 feet per second at 1.1 degrees to 111 feet per second at a temperature between 0.5 and 0.7 degrees. This confirms Landau's thesis that superfluid atoms have a zero thermal energy content.

Cryogenic researchers have scant hope of ever achieving absolute zero, but the Bureau's verification of Landau's theory raises the possibility that experimenters will come closer to that ideal condition. This could be done by separating superfluid from the normal fluid of Helium II, and utilizing the superfluid's zero-energy properties.

A New Automatic Load Control for Turbine Generators

H. B. RUUD S. B. FARNHAM
MEMBER AIEE

IN AN interconnected power system, load changes sufficient to affect system frequency are shared by all the generators on the system in proportion to their ratings and their governor characteristics. While this is desirable in most instances, it may present a problem where large fluctuating loads are remote from major sources of generation. Such a problem exists in the case of a new aluminum rolling mill near Davenport, Iowa, whose electrical requirements are supplied by the Iowa-Illinois Gas and Electric Company. The mill load swings are expected to vary between 5,000 and 8,000 kw above and below the mean load (16,000 kw maximum total swing) and vary at a rate of between 2,000 and 5,000 kw per second.

In order to confine these swings to the local generators, rather than letting them flow over the 161-kv transmission line which links the Iowa-Illinois Gas and Electric Company system with other utilities in Iowa and Missouri, a new type of automatic load-regulating equipment is being installed on the turbine-generator sets at the Riverside Station, which is adjacent to the aluminum mill. This equipment will cause the controlled machines to vary their power output rapidly in response to the demands of the mill, and in anticipation of any change in system frequency. Thus, the remote machines on the interconnected system will be unaware of the mill load changes, and this fluctuating load will be confined locally to the controlled machines. In operation, the load control function can be assigned to any one of four machines in the Riverside Station, or divided among them in any desired proportion. While a controlled machine can also carry system base load, sufficient margin must be left to permit its picking up its assigned share of the mill load swings as they occur. This in general will militate toward the use of the older, less efficient machines for load regulation, leaving the newer machines for base-load operation.

The controlling quantity is derived from instrument transformers in the mill feeders, and is introduced into a bridge circuit which can be balanced at any predetermined value of generator base load. Variations in the mill load, by upsetting the balance of the bridge, produce a voltage at the terminals of a continuously driven amplidyne generator. This voltage operates the main generator synchronizing motor, which is somewhat oversized to afford the necessary high speed of response, and thereby causes more or less steam to be admitted to the turbine as is required to handle the changed load. Balance of the bridge is re-established at the new load level through a follow-up system which introduces into the bridge circuit a voltage proportional to the turbine valve position, and hence to kilowatt load. Refinements in the circuit permit operation of the synchronizing motor at conventional speed as required for manual synchronizing and for operation in conjunction with the usual tie-line bias control equipment.

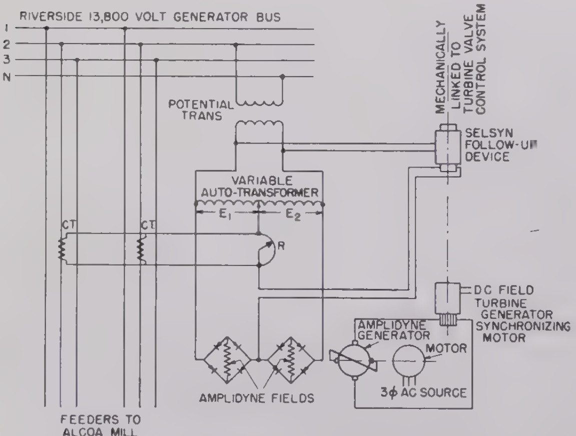
RIVERSIDE 13,800 VOLT GENERATOR BUS
1
2
3
N
POTENTIAL TRANS
MECHANICALLY LINKED TO TURBINE VALVE CONTROL SYSTEM
SELSYN FOLLOW-UP DEVICE
VARIABLE AUTO-TRANSFORMER
E1
E2
CT
CT
R
DC FIELD
TURBINE GENERATOR SYNCHRONIZING MOTOR
AMPLIDYNE GENERATOR
MOTOR
3φ AC SOURCE
AMPLIDYNE FIELDS
FEEDERS TO ALCOA MILL

Figure 1. Simplified diagram of automatic control circuit

It is to be noted in Figure 1 that the reference voltages and the follow-up voltages are supplied from a common source. Not only must these voltages be in phase with one another, but also they must be derived from the same phase in which the current transformers for the Alcoa load are connected.

Other somewhat similar load control arrangements have had the common characteristic that when the automatic load-regulating feature was in service, the speed governor was rendered inoperative, except that on overspeed it could take precedence and shut down the machine. Conversely, when the machine was under the control of its speed governor, the load-control feature was necessarily disconnected. Never before has it been possible to operate a machine under both types of control simultaneously. Such a limitation has not been detrimental in past installations since they concerned relatively small machines serving industrial power systems which were interconnected with larger utility systems. In these instances, it was not expected that the industries' generators would help support the frequency of the interconnected systems.

The requirements at Riverside, however, in common with any similar station on a utility system, are such that in the event of an emergency each machine must be able to contribute its full capabilities toward maintaining system frequency. That is, its speed governor must at all times be fully operative to help support system frequency. The new load control equipment is believed to be unique in its ability to do this while simultaneously performing its special function of confining the aluminum mill load swings to the local generation.

Digest of paper **49-289,** "A New Automatic Load Control for Turbine Generators," recommended by the AIEE Power Generation Committee and approved by the AIEE Technical Program Committee for presentation at the AIEE Fall General Meeting, Cincinnati, Ohio, October 17–21, 1949. Scheduled for publication in AIEE *Transactions*, volume 68, 1949.

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Vibration Pressure Hypothesis for Electric Repulsion

H. B. DWIGHT
FELLOW AIEE

In this article, Professor H. B. Dwight considers the similarity of the equation for the net repulsion between moving charges and the equations for sound pressure from one moving body on another moving body. Because of the similarity of the equations, he speculates that the force which causes electrostatic repulsion is a form of radiation.

TWO ELECTRIC charges of the same sign have been observed, since the early experiments with frictional electricity and pith balls, to repel each other. An electrified pith ball is said to have an electric field, and a second one near it lies in that field and is repelled. The mechanical force is "action at a distance," and standard books give no description or explanation of what causes the mechanical force or what is happening between the two charges to convey the action from one to the other. Such a description is not given by saying that there is an electric field at all points between the two charges—that is merely stating that a charge placed at any of the points will be repelled, always by action at a distance. Electrostatic repulsion is thus one of the mysteries of science.

The force between two concentrated charges, q_1 and q_2 electrostatic units or statcoulombs, separated by r centimeters, is

$$\frac{q_1 q_2}{r^2} \text{ dynes}$$

The same force that causes pith balls to repel also causes a beam of electrons to spread or diverge.

There is another mechanical force acting at a distance, namely, the magnetic attraction between two parallel currents of the same sign. If the charges q_1 and q_2 are moving in parallel directions with velocity v and are abreast of each other at a separation of r centimeters, they represent currents of $q_1 v/c$ and $q_2 v/c$ abamperes where c is the conversion factor between electromagnetic and electrostatic units of charge. By Ampère's formula, putting $\sin \theta = 1$, the attraction is

$$\frac{q_1 q_2}{r^2} \frac{v^2}{c^2}$$

which is the same as

$$\frac{i_1 dl_1 i_2 dl_2}{r^2}$$

The net repulsion between moving charges in this case is

$$\frac{q_1 q_2}{r^2}\left(1 - \frac{v^2}{c^2}\right) \tag{1}$$

This expression is experimental, being based on electrical measurements.

An effect occurs in connection with sound which has a strong resemblance to equation 1. If two automobiles A and B, Figure 1, are abreast at distance r, and moving with velocity v, and if sound is sent out from A, the sound which reaches B at the instant illustrated has traveled along the sloping line of length st, where s is the speed of sound and t is the time of the travel. The intensity of the sound and the pressure on an object which it strikes vary inversely as s^2t^2 if the sound is sent out uniformly in all directions. The ratio of the pressure on B, to the pressure P when A and B are stationary, is

$$\frac{r^2}{s^2t^2} = \frac{s^2t^2 - v^2t^2}{s^2t^2} = 1 - \frac{v^2}{s^2}$$

$$\text{Pressure} = P\left(1 - \frac{v^2}{s^2}\right) \tag{2}$$

In this simple case the sound appears to B to arrive along the direction of r, Figure 1, and the frequency is the same as for the stationary case. There is no change in angle or frequency from Doppler effect.

The second term of equation 2, namely, $-Pv^2/s^2$ is the reduction in P because of motion. It corresponds to the second term in the bracket of equation 1, which is the magnetic force. It may then be said that there is a "magnetic" attractive force on automobile B due to sound pressure. It is, of course, purely mechanical and has nothing to do with magnetism.

With sound waves, the action by which the energy is carried from one body to another and exerts pressure on it can be traced mechanically in detail and is not to be called action at a distance.

The similarity of equations 1 and 2 could suggest that equation 1 as well as equation 2 is an expression for vibration pressure, corrected for the motion v of the source. Since, as is well known, the electrical conversion factor c agrees with the numerical value of the velocity of radiation with high precision, the suggestion would follow that the vibration which gives electrostatic repulsion is radiation. This is natural, for radiation is the only vibration we know that goes through brick walls or a vacuum, as magnetism does.

The hypothesis that electric force, gravity, and inertia are manifestations of radiation pressure was published in 1931 by the late Professor James Mackaye of Dartmouth

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College in his book "The Dynamic Universe."[1] He described attraction as a reduction in repulsion or a shielding from outside repulsion. Thus, our weight would represent a pressure by radiation from the sky, the earth shielding us from radiation coming from the opposite direction.

In 1929, this writer made the preliminary calculations for chapter 36 of his book "Electrical Coils and Conductors"[2] and used the hypothesis that electric repulsion was radiation pressure and was subject to Doppler effect before he had heard of Mackaye's hypothesis.

For many years, the electromagnetic laws have been derived in the books by Leigh Page[3,4,5] by computing electric repulsions and attractions and using relativity corrections where there are moving charges. The corrections are of the form of powers of $(1-v^2/c^2)$, similar to the bracketed part of equations 1 and 2.

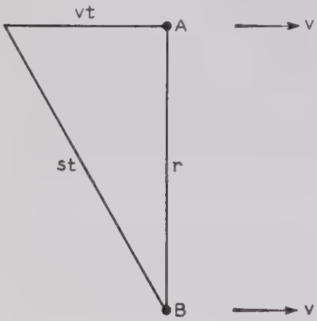

Figure 1. *A* and *B* are moving at a velocity *v*, and a sound emanates from *A*

The radiation assumed by Mackaye's hypothesis, as regards electric forces, acts on electrons, which are much smaller than atoms or molecules. Such radiation would be expected to have wave lengths of a lower order of magnitude than those of radiation which would affect molecules, or photographic film, or other laboratory apparatus. It might be that the only evidence of such radiation would be the familiar pressure produced. If so, information is more likely to be obtained by calculation than by measurements.

The mobile electrons are held inside a metal wire by something like surface tension, as is shown by the difficulty of emission of electrons from electrodes when cold. If a direct current is flowing in a wire and a second portion of insulated wire is held at right angles to the first and moved in the direction of the current flow, we have a case similar to Figure 1. The electrons in the second wire are urged along it; that is, an electromotive force is induced in it and a current would flow if a metal path were provided. The "surface tension" of the second wire, which makes the electrons partake of the sideways motion of the wire, is a necessary part of the problem. This is a simple case of motional electromotive force.

In conclusion, to state that there is an electric or magnetic field is merely to say that action, producing force, can take place at a distance, and this leaves a gap in our knowledge as to what is happening to convey the action across the distance. Mackaye's hypothesis of radiation pressure proposes an explanation to fill this gap in present knowledge. To propose a hypothesis is a scientific procedure. This hypothesis does not seem to call for a change in any present formula or equation. No fact appears to have been brought forward by which one must say "It is impossible that electrostatic repulsion is radiation pressure." No other hypothesis seems to have been published that offers an explanation of the mystery of these actions at a distance.

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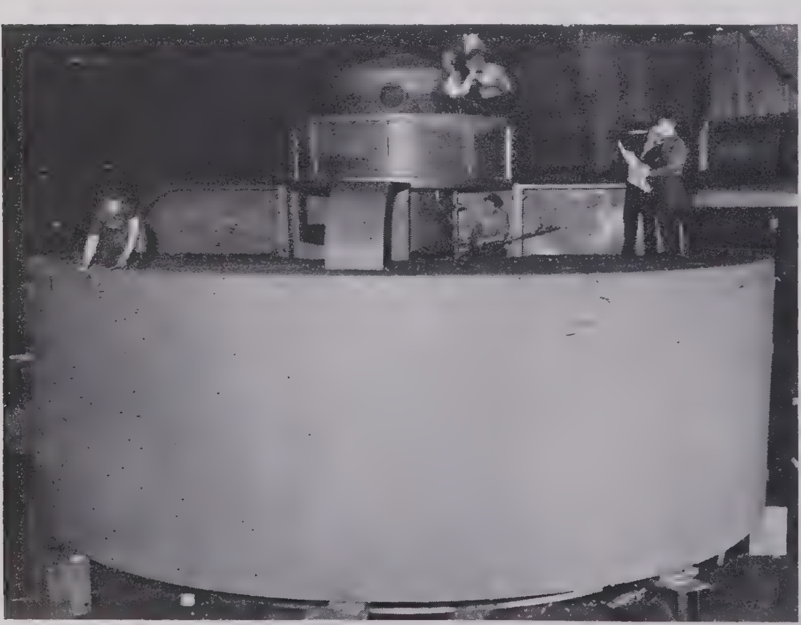
Giant Grand Coulee Motor



Workmen are making final adjustments on a 330-ton 65,000-horsepower motor, slated to be installed in the Bureau of Reclamation's new pumping plant at Grand Coulee Dam on the Columbia River. This and an identical machine will help irrigate a vast expanse of rich but dry land in south-central Washington. Built by the General Electric Company, the two motors will drive the world's largest pumps, each capable of moving enough water to equal the daily requirements of 35 cities the size of Schenectady, N. Y. Operating under optimum conditions, each pump will supply more than a billion gallons of water a day. Each of the huge motors is 25 feet high and 100 feet around the base. Because of their tremendous size, they had to be partially disassembled for shipment. Installation in the pumping plant will start about August 1950, and pumping of water will begin in May 1951

1950 Employment Programs for Graduates in Engineering and Physical Science

Inspired by the success of its 1949 survey of employment programs for engineering graduates, the General Survey Committee of the Engineers Joint Council has completed a similar survey for 1950. One important result of the present survey, the substantial decrease in demand for graduates by the organizations participating, would seem to indicate the importance of seeking opportunities in the great number of relatively smaller industries not covered by the survey because of their lack of organized employment programs.

IN VIEW of the response to its 1949 survey of employment programs for engineering graduates and the interest in that survey's results (see *EE, Jul '49, pp 565–8*), the General Survey Committee of the Engineers Joint Council now has completed a similar survey of the 1950 programs.

The points covered by the new survey are as follows:

1. The relative demand in 1949 and 1950 for inexperienced graduates in engineering and physical science from industry, government, and the engineering colleges. Last year's survey did not cover graduates in physical science or the demands from engineering colleges. More detailed information concerning the numbers of men sought with bachelor's, master's, and doctor's degrees was requested this year.
2. The 1950 starting salaries for such graduates with bachelor's, master's, and doctor's degrees, together with related information on differentials by curricula, credits for military service, and increases during the first year of employment.

Information secured last year concerning the trend of salaries for engineering graduates ten years out of college was not requested in 1950.

In order to appraise the nature of the sample covered, both surveys requested information concerning the character of the responding organization, its total number of employees, and the number of graduates in engineering and in physical science in its employ.

By concentrating in part on organizations responding last year, this year's survey was limited to 311 industrial companies and 45 governmental agencies. The 114 engineering colleges included were those for which, with a few minor exceptions, the dean or president was listed in the 1949 year book for the American Society for Engineering Education. Information requested from these institutions concerned only teaching and research positions requiring more than half-time service. Usable information in regard to engineering graduates was received in time for tabulation from 144 companies, 70 per cent of which responded last year, 23 government agencies, all but one of which did so, and 64 engineering schools. Eighty-five of the companies, 11 of the government agencies, and 28 of the engineering schools also provided data concerning graduates in physical science. In particular, such data were not furnished by schools associated with universities for which the teaching in these fields was carried on by the arts and sciences college.

Although the total number of companies and governmental agencies covered is 167, as compared with 198 last year, it is believed that an excellent sample of organizations with definite employment programs for technical graduates has been secured. As suggested in the discussion following, it is probably not a good sample of the entire corresponding field of opportunity for such graduates. The sample for the engineering colleges seems entirely adequate.

SUMMARY OF THE FINDINGS

THE industrial companies providing data on their engineering graduates have a total of 3,090,000 employees, of whom 66,400 are graduate engineers. Since the government agencies included, in general, are technical branches of other organizations, their total employee figures have little significance, and this is also true of the engineering colleges. The agencies, however, have 18,200 graduate engineers in their employ, and the colleges 6,800. Engineering graduates in all organizations covered, therefore, total 91,400. The organizations also giving figures for graduates in physical science have 13,100 such graduates and 60,000 engineering graduates employed.

The former organizations state that they employed nearly 8,000 engineering graduates in 1949 and expect to hire 5,550, or 30 per cent fewer, in 1950. For the industrial companies, the decrease is 28 per cent to a total of 3,825; for the government agencies, it is 33 per cent to 1,420; and for the engineering colleges, it is 44 per cent to 310. Decreases are characteristic of all the large industrial groups, except chemical companies, and of both federal and state agencies.

The latter organizations employed 1,500 graduates in physical science in 1949 and expect to hire 1,250, or 16 per cent less, in 1950. For the industrial companies, the decrease is 18 per cent to 900; for the engineering colleges, 55 per cent to 100; the governmental agencies, however, expect an increase of 40 per cent to 250. With smaller numbers, variations by individual industry are of less significance, but the chemical industry shows a substantial increase here also.

The estimated employment for engineering graduates includes 600 chemical engineers, 1,350 civil engineers, 1,410 electrical engineers, and 1,530 mechanical engineers, with smaller numbers from other curricula. Of the graduates in physical science, 660 are expected to be

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Full text of a report issued by the General Survey Committee of the Engineers Joint Council.

employed as chemists, 415 as physicists, and 170 trained in other related fields.

By engineering curricula, the decreases in expected employment are all of the same general order of about 30 per cent, except that a decrease of only 5 per cent from 1949 is expected in chemical engineering. Among physical science graduates, the employment of chemists is expected to decrease by 14 per cent, but that of physicists to increase by 7 per cent. In both general fields, decreases are expected at the bachelor's and master's level, but an increase of 27 per cent at the doctor's level.

With few exceptions, the reporting organizations use the same basic starting rates for all engineering and physical science graduates at each degree level. Among the bachelors, 25 per cent will receive a rate of $275 per month or more, 50 per cent a rate of $255 a month or more (the so-called median), and 75 per cent one of $245 or more. The median for the industrial companies is also $255, but the corresponding figure for the governmental agencies and colleges is $260. For organizations seeking primarily chemical engineers the median is $280; for other organizations seeking mainly civil, electrical, or mechanical engineers, only small variations from the general $255 figure occur. Among industries, the highest medians are found in the chemical and petroleum companies, $300 and $290 per month, respectively.

For technical graduates receiving master's degrees, the over-all median is $320 per month, and this figure is also found in the governmental agencies and engineering colleges. In indus-

Table I. Employment of Engineering Graduates by Industry, Government, and Engineering Colleges

Employing Organization	Number of Organizations	Total Employees	Engineering Graduates: Total in Companies	Hired 1949	Quotas 1950	Per Cent Change
Industrial						
Aircraft	2	26,000	700	48	27	−43.7
Automotive	8	615,800	4,419	396	342	−13.6
Building materials	6	31,510	511	41	18	−56.0
Chemical	12	113,519	4,803	314	425	+35.3
Consulting	4	14,395	1,589	144	59	−59.0
Electrical	8	411,300	18,450	1,514	1,057	−30.2
Food	6	107,050	872	53	53	
Glass	2	14,700	390	14	6	−57.0
Instruments	7	11,798	1,347	143	80	−44.0
Machinery	17	114,675	5,094	425	265	−37.6
Metals	13	227,954	4,597	582	382	−34.4
Mining	2	22,587	185	34	23	−32.4
Paper	9	32,560	599	59	49	−17.0
Petroleum	7	155,210	4,543	277	197	−29.0
Public utility	22	650,721	12,071	754	517	−31.4
Rubber	5	162,300	2,610	172	129	−25.0
Shipbuilding	2	8,400	105	51	2	−96.0
Soap	2	18,700	950	127	95	−25.2
Textiles	5	20,725	198	28	33	+17.7
Transportation	5	330,998	2,334	143	66	−53.8
Total	144	3,090,902	66,367	5,261	3,825	−28.4
Government						
Federal	10		12,991	1,037	790	−24.7
State	13		5,202	1,098	632	−42.5
Total	23		18,193	2,135	1,422	−33.3
Engineering Colleges	64		6,831	557	310	−44.5
Grand total	231		91,391	7,953	5,557	−30.2

Table II. Employment of Graduates in Physical Science by Industry, Government, and Engineering Colleges

Employing Organizations	Number of Organizations	Total Employees	Total Engineering Graduates	Physical Science Graduates: Total in Companies	Hired 1949	Quotas 1950	Per Cent Change
Industrial							
Aircraft	1	12,000	350	20			x
Automotive	6	232,300	1,838	190	125	25	−80.0
Building materials	4	19,510	158	103	9	9	x
Chemical	12	113,519	4,803	3,450	204	251	+23.2
Consulting	2	12,600	814	240	10	13	+30.0
Electrical	4	362,000	15,850	2,538	343	330	− 3.8
Food	5	101,050	841	544	23	15	−34.8
Glass	2	14,700	390	301	4	1	x
Instruments	6	10,698	1,147	68	3	3	x
Machinery	7	31,323	900	200	10	5	−50.0
Metals	5	21,384	1,057	100	21	10	−42.5
Mining	1	16,587	155	21	7	5	x
Paper	5	15,800	321	102	11	4	−63.7
Petroleum	5	78,710	3,043	1,197	178	111	−37.6
Public utility	10	567,385	9,136	865	36	22	−38.8
Rubber	4	122,300	2,260	571	49	31	−36.6
Shipbuilding	1	1,200	30	2	4		x
Soap	2	18,700	950	280	26	38	+46.2
Textiles	2	16,000	170	113	16	21	+31.2
Transportation	1	21,633	69	3			x
Total	85	1,789,399	44,272	10,910	1,079	894	−18.0
Government							
Federal	5		9,747	724	180	251	+39.5
State	6		1,882	63	1	2	x
Total	11		11,629	787	181	253	+40.0
Engineering Colleges	28		3,646	1,447	215	97	−55.0
Grand Total	124		59,547	13,144	1,475	1,244	−15.6

x Not given since base less than ten cases.

Table III. Employment of Engineering Graduates by Size of Industrial Companies

Number of Employees	Number of Companies	Total Employees	Engineering Graduates: Total in Companies	Hired 1949	Quotas 1950	Per Cent Change
Less than 5,000	66	136,742	6,671	623	414	−33.6
5,000– 9,999	32	221,177	8,491	620	434	−30.0
10,000–99,999	39	1,186,628	28,990	2,068	1,649	−20.2
100,000 and over	7	1,546,365	22,215	1,950	1,328	−31.9
Total	144	3,090,902	66,367	5,261	3,825	−28.4

trial companies, it is $5 higher. At the doctor's level, the over-all median of $445 is found also in industry and government, but in the engineering colleges the corresponding rate is $390. At this level there are no significant variations in the median rates of organizations seeking men from different curricula. At the master's level, however, those employing primarily chemical engineers use a median rate of $335; those employing primarily electricals, one of $295.

For all the organizations reporting and for the industrial companies included, the median total increase by the end of the first year of employment is $25 per month, but for the engineering colleges this figure is $20 and for the governmental agencies, $12. In all organizations, 65 per cent give this increase at one time, 33 per cent in two installments, and only 2 per cent in three bites. In only one-third of all organizations, but two-thirds of the governmental agencies, is it on an automatic rather than merit basis.

Table IV. Employment of Graduates in the Field of Physical Science by Size of Industrial Companies

Number of Employees	Number of Companies	Total Employees	Total Engineers	Graduates in Physical Science Total	Hired 1949	Quotas 1950	Per Cent Change
Less than 5,000	43	93,926	3,873	1,108	60	71	+18.5
5,000– 9,999	16	110,460	4,934	1,754	119	89	−25.3
10,000–99,999	23	750,013	19,165	5,848	490	434	−11.4
100,000 and over	3	835,000	16,300	2,200	410	300	−26.8
Total	85	1,789,399	44,272	10,910	1,079	894	−15.6

Table V. 1950 Quotas of Engineering Graduates by Curricula and Industry, Government, and Engineering Colleges

Employing Organizations	Number of Organizations	Aero.	Chem.	Civil	Elec.	Ind.	Mech.	Min.	Met.	Other	Total
Industrial											
Aircraft	2	11			6		10				27
Automotive	7	14	18	5	53	34	183		14	21	342
Building materials	3				11		7				18
Chemical	9	1	252	7	20	20	115		8	2	425
Consulting	4		4	14	25		16				59
Electrical	7	5	36	5	522	41	401		37	10	1,057
Food	6		8	10	2	5	28				53
Glass	1		1				4			1	6
Instruments	5		4		43	2	31				80
Machinery	15		8	4	48	11	176	1	6	11	265
Metals	12	2	16	20	42	58	150	3	72	19	382
Mining	2		5		3	1	4	10			23
Paper	9		23	1	1	6	18				49
Petroleum	7		58	18	17		45	20		39	197
Public utility	18		7	28	338	28	111			5	517
Rubber	3		38	2	18	19	39			13	129
Shipbuilding	1									2	2
Soap	2		55	2	7	6	25				95
Textiles	5		3			12	2			16	33
Transportation	5			55	7		4				66
Total	123	33	536	171	1,163	243	1,369	34	137	139	3,825
Government											
Federal	10	45	21	402	188	1	108		2	23	790
State	12		3	618	3		4		2	2	632
Total	22	45	24	1,020	191	1	112		4	25	1,422
Engineering Colleges	40	25	36	60	56	10	52	4	7	60	310
Grand total	207	103	596	1,351	1,410	254	1,533	38	148	224	5,557

Only about one-quarter of the total number of industrial and governmental organizations with 1950 quotas for engineering graduates report starting rates for graduates in business administration and even fewer a rate for those in arts. At the bachelor's level, a median rate of $250 is found for both curricula (as compared with $255 for technical graduates) and at the master's level, the medians are $275 and $270 respectively (against $320).

Table VI. 1950 Quotas of Graduates in Physical Science by Type of Curricula and by Industry, Government, and Engineering Colleges

Employing Organizations	Number of Organizations	Chemical	Physical	Other	Total
Industrial					
Automotive	2	1	1	23	25
Building materials	1	8	1		9
Chemical	9	229	14	8	251
Consulting	1	4	2	7	13
Electrical	4	142	153	35	330
Foods	4	15			15
Glass	1	1			1
Instruments	1		3		3
Machinery	2	1	3	1	5
Metals	4	6		4	10
Mining	1	3		2	5
Paper	4	4			4
Petroleum	5	83	12	16	111
Public utility	3	2	13	7	22
Rubber	3	24	7		31
Soap	2	38			38
Textiles	2	4		17	21
Total	49	565	209	120	894
Government					
Federal	6	40	166	45	251
State	2	2			2
Total	8	42	166	45	253
Engineering Colleges	23	51	40	6	97
Grand total	80	658	415	171	1,244

DISCUSSION OF THESE FINDINGS

With respect to starting rates, the significant point is that those for bachelors have changed very little since 1949. The over-all median is the same but the relatively high medians then found for organizations seeking primarily chemical and mechanical engineers have dropped $10 per month. At the master's and doctor's levels, however, the increased medians indicate a higher evaluation of the advanced training. Increases during the first year tend to be somewhat smaller and to be given at one time, usually later in the period.

The marked relative decline in the number of organizations giving rates for business and arts graduates indicates that, within these organizations, employment of such

Table VII. 1950 Employment of Technical Graduates by Curricula and Activity Areas—Training Levels Combined

Curricula	Industry		Government		Engineering Colleges		Total	
	Quota	Per Cent Change	Quota	Per Cent Change	Quota	Per Cent Change	Quota	Per Cent Change
Engineering								
Aeronautical	33	−31.2	45	−40.0	25	−3.8	103	−30.8
Chemical	536	−3.1	24	−17.2	36	−20.0	596	−5.0
Civil	171	−36.0	1,020	−33.0	60	−44.4	1,251	−34.0
Electrical	1,163	−35.1	191	−35.7	56	−60.9	1,410	−36.8
Industrial	243	−31.0	1	x	10	−60.0	254	−33.2
Mechanical	1,369	−24.2	112	−36.0	52	−40.8	1,533	−26.8
Mining	34	−27.7			4	x	38	−29.6
Metallurgy	137	−16.5	4	x	7	−50.0	148	−17.7
Other	139	−33.2	25	−19.5	60	−40.7	224	−34.2
Total	3,825	−28.4	1,422	−33.3	310	−44.5	5,557	−30.2
Physical Science								
Chemical	565	−3.5	42	−17.6	51	−57.2	658	−14.0
Physics	209	−17.6	166	+80.4	40	−42.8	415	+7.5
Other	120	−49.8	45	+18.5	6	−62.5	171	−41.8
Total	894	−18.0	253	+39.8	97	−54.9	1,244	−15.6

x Base less than ten cases.

Table VIII. 1950 Employment of Technical Graduates by Training Levels and Activity Areas—Curricula Combined

Training Levels	Industry		Government		Engineering Colleges		Total	
	Quota	Per Cent Change	Quota	Per Cent Change	Quota	Per Cent Change	Quota	Per Cent Change
Engineering								
Bachelors	3,424	−29.6	1,352	−35.8	128	−58.8	4,904	−32.7
Masters	299	−6.5	65	+160.0	125	−35.8	489	−9.4
Doctors	102	+39.5	5	x	57	+11.6	164	+27.0
Total	3,825	−28.4	1,422	−33.3	310	−44 5	5,557	−30.2
Physical Science								
Bachelors	387	−45.2	140	+12.9	27	−68.4	554	−31.3
Masters	155	−24.8	30	+150.0	24	−66.7	209	−28.0
Doctors	352	+27.5	83	+84.4	46	−19.2	481	+27.2
Total	894	−18.0	253	+39.8	97	−54.9	1,244	−15.6

Table IX. 1950 Employment of Technical Graduates by Curricula and Training Levels—Activity Areas Combined

Curricula	Bachelors		Masters		Doctors		Total	
	Quota	Per Cent Change	Quota	Per Cent Change	Quota	Per Cent Change	Quota	Per Cent Change
Engineering								
Aeronautical	80	−37.0	19		4	x	103	−30.8
Chemical	400	−7.8	120	−9.8	76	+26.5	596	−5.0
Civil	1,169	−35.9	72	+10.8	10	−9.2	1,251	−34.0
Electrical	1,272	−38.8	111		27	+35.0	1,410	−36.8
Industrial	243	−31.4	9	−60.7	2	x	254	−33.2
Mechanical	1,406	−28.6	107	−2.6	20	x	1,533	−26.8
Mining	28	−40.4	9	x	1	x	38	−29.6
Metal	117	−19.2	16	−30.4	15	+36.5	148	−17.7
Other	189	−37.1	26	−8.0	9	−18.2	224	−34.2
Total	4,904	−32.7	489	−9.4	164	+27.0	5,557	−30.2
Physical Science								
Chemical	255	−28.8	98	−38.4	305	+22.3	658	−14.0
Physics	180	−17.8	84	−12.5	151	+49.7	415	+7.5
Other	119	−48.3	27	−22.8	25	−10.7	171	−41.8
Total	554	−31.3	209	−28.0	481	+27.2	1,244	−15.6

x Base less than ten cases.

graduates probably will drop more sharply than that of technical graduates. The major value of the survey seems to be in the light it can throw on the country's requirements for engineering graduates. The lack of background figures for those with physical science degrees makes it unwise to attempt any general interpretation of those secured for them.

Extrapolation of the demand for engineering graduates reported in the 1949 survey, in terms of the proportion of all such graduates in the profession represented by the participating organizations, indicated a total demand in that year for some 25,000 new graduates. The committee's survey of actual placements up to November covering engineering schools with three-fourths of the year's total graduates, showed that they were about 50 per cent higher than that figure and total placements presumably were still greater.

The major part of this difference seems to lie in the opportunities found in the great number of relatively small organizations impossible to cover in a limited survey of this type, most of which do not have organized employment programs. Although the 1949 returns represented almost one-third of the country's engineering graduates in the profession, they covered less than one-sixth of its industry in terms of total employees. By industry, here is meant not only manufacturing, but mining, construction, transportation, and other public utilities and comparable activities in government. Some of these smaller organizations may not have been able to secure satisfactory engineering graduates in the intense competition shortly after the war; others may not have previously recognized needs for such men.

With the larger graduating class this year and the substantial decrease in the demand from organizations participating in this survey, intensive cultivation of the smaller organizations for openings not only in engineering but in production and operations, leading to supervision and sales, offers the best chance for satisfactory placement results. In view of the situation, moreover, employing organizations with either immediate or long-term needs for men with technical training have an exceptional chance to fill such needs with carefully selected men. About 51,000 bachelor's degrees will be given in engineering during 1950. Next year the total will be 30 per cent less,

Table X. Monthly Base Starting Rates Technical Graduates With Bachelors' Degrees

Areas	1950 Quotas	Medians Upper Half	Medians Whole Group	Medians Lower Half
	By Major Activity Areas			
Industry	3,884	$270	$255	$245
Government	1,492	280	260	240
Engineering colleges	148	280	260	250
Total	5,524	$275	$255	$245

Curricula	1950 Quotas	Medians Upper Half	Medians Whole Group	Medians Lower Half
	By Principal Curricula Used in Industry and Government			
Chemical	809	$295	$280	$265
Civil	1,125	275	260	240
Electrical	2,104	255	250	245
Mechanical, aeronautical, or industrial	1,258	275	255	245
Other	80	300	245	235
Total	5,376	$275	$255	$245

Table XI. Monthly Base Starting Rates Technical Graduates With Bachelors' Degrees by Industry, Government, and Engineering Colleges

Employing Organizations	Number of Organizations	1950 Quotas	Median Rates
Industrial			
Automotive and aircraft	10	377	$275
Chemical	12	285	300
Electrical	8	1,122	245
Machinery	17	256	245
Metals	13	388	255
Petroleum	7	239	290
Public utilities	22	491	250
Rubber	5	148	255
Governmental			
Federal	10	862	$260
State	13	630	260
Engineering Colleges	64	148	260

Table XII. Monthly Base Starting Rates Technical Graduates by Educational Levels

Areas	Bachelors 1950 Quotas	Bachelors Medians	Masters 1950 Quotas	Masters Medians	Doctors 1950 Quotas	Doctors Medians
	By Major Activity Areas					
Industry	3,884	$255	447	$325	447	$445
Government	1,492	260	95	320	88	445
Engineering colleges	148	260	135	320	86	390
Totals	5,524	$255	677	$320	621	$445

Curricula	Bachelors 1950 Quotas	Bachelors Medians	Masters 1950 Quotas	Masters Medians	Doctors 1950 Quotas	Doctors Medians
	By Principal Curricula Used in Industry and Government					
Chemical	809	$280	213	$335	318	$445
Civil	1,125	260	57	320		
Electrical	2,104	250	216	295	126	450
Mechanical, aeronautical, or industrial	1,258	255	54	320	91	445
Other	80	245	2	*		
Total	5,376	$255	542	$320	535	$445

* Not significant.

and, on the basis of freshman and sophomore enrollments, there will be further sharp declines in 1952 and 1953.

DETAILED RESULTS OF THE 1950 SURVEY

The tables included in this article present the 1950 survey results in considerable detail but this should permit readers to identify those bearing on points of special interest. Since, in general, the tables speak for themselves, the text is primarily explanation rather than comment.

Tables I and II present comparable information for organizations reporting on their programs for engineering and for physical science graduates. Undoubtedly some of those in the former but not in the latter group employ graduates in physical science without any definite program in that field. The column on "Total Engineering Graduates" in Table II makes it possible to compare the relative numbers of such graduates and of those in physical science in the various organizations.

Tables III and IV show how the industrial companies responding are distributed with respect to total numbers of employees. Although the smaller ones included show a relatively large drop in expected demand for engineering graduates, these are mainly organizations with continuous technical employment programs and it is not felt that their situation is typical of other smaller organizations.

Table XIII. Salary Increases During First Year of Employment

Areas	Number of Organizations*	Number of Increases 1	Number of Increases 2	Number of Increases 3	Automatic	Merit	Medians Top Half	Medians All	Medians Lower Half
	By Major Activity Area								
	(Percentages of Totals)								
Industry	126	52.0	45.6	2.4	36.4	63.6	$30	$25	$20
Government	20	80.0	20.0		68.2	31.8	16	12	10
Engineering colleges	39	97.6	2.4		7.7	92.3	25	20	15
Total	185	65.1	33.3	1.6	32.5	67.5	$30	$25	$15
	By Principal Curricula in Industry and Government								
Curricula									
Chemical	33	63.6	36.4		18.2	81.8	$30	$25	$25
Civil	18	83.3	16.7		60.0	40.0	15	10	10
Electrical	47	45.8	50.0	4.2	41.7	58.3	30	25	20
Mechanical, aeronautical, or industrial	42	47.6	50.0	2.4	41.0	59.0	40	25	20
Other	6	66.7	33.3			100.0	50	25	20
Total	146	55.8	42.1	2.1	36.6	63.4	$30	$25	$20

* Providing data on amount of increase; numbers for other items vary slightly.

In Tables V and VI, the numbers of organizations shown are those expecting to employ one or more of the types of graduates indicated in 1950. The differences between these numbers and those in Tables I and II show how many organizations in each group reported on employment programs but stated that their 1950 quota was zero.

Table XIV. Monthly Base Starting Rates Engineering, Business, and Arts Graduates by Principal Engineering Curriculum Used

Curricula	Number of Organizations Reporting*			Medians		
	Engineering	Business	Arts	Engineering	Business	Arts
Bachelors' Degrees						
Chemical	31	12	7	$280	$250	$250
Civil	21	1	1	260	215	210
Electrical	40	12	4	250	250	255
Mechanical, aeronautical, or industrial	44	7	3	255	225	215
Other	9			245		
Total	145	32	15	$255	$250	$250
Masters' Degrees						
Chemical	19	5	4	$335	$275	$275
Civil	4	1	1	320	215	215
Electrical	12	4	3	295	270	265
Mechanical, aeronautical, or industrial	7	2	1	320	300	320
Other	1					
Total	43	12	9	$320	$275	$270

* Industry and government only.

Tables VII, VIII, and IX break down the 1950 quotas in various ways and in each case show the magnitude of the change from 1949.

In the lower block of Table X, rates are shown for organizations seeking men primarily from a particular engineering curriculum. For example, primarily chemical engineers are sought by the chemical, petroleum, and other industries and their rates have been compiled on the "Chemical" line. Only 13 organizations show variations in their rates for men at the bachelor's level from different curricula and the total quotas of seven of these organizations are less than ten men. Where differentials are paid, they usually are in favor of civil, chemical, or petroleum engineers as compared with electricals, mechanicals, or industrials.

In addition to their base rate figures, organizations were asked to indicate whether or not they paid a differential for military service. Only 24 organizations, all industrial companies, state that they do so. Four of these are electrical companies and four public utilities, with the rest scattering. Practically all pay on the basis of experience related to the prospective assignment and in half of the cases the usual amount given is not stated. In 7 of the remaining 12 cases, it is between $10 and $20 per month.

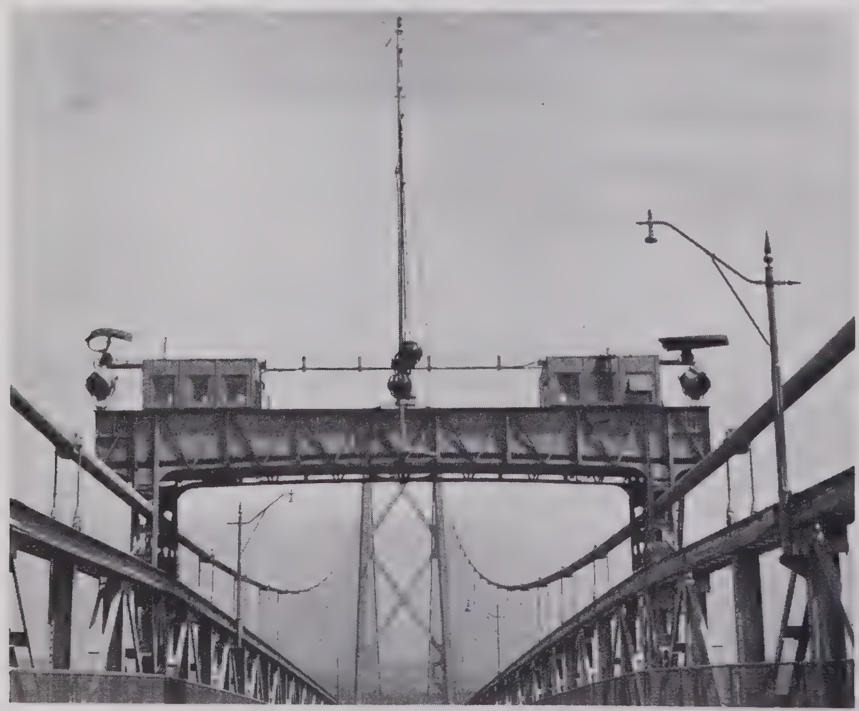
Table XI shows the bachelor's median rates for different types of employing organizations.

Table XII shows median rates by educational levels, types of employing organizations, and major curricula sought.

Table XIII concerning salary increases during the first year of employment follows a similar pattern.

Although no information was requested concerning the magnitude of employment plans for graduates in business administration and arts and science (other than physical science), the starting rates used were requested and presumably are given by organizations expecting some employment of such men. In Table XIV, the number of engineering organizations shown includes only those planning to employ some technical graduates in 1950 and it appears that only about 25 per cent as many expect to hire business graduates and even fewer arts graduates.

Although at the bachelor's level the over-all medians for these graduates are only slightly below that for technical graduates within groups of organizations seeking engineers from particular engineering curricula, there is usually a substantial differential in favor of the engineers. At the master's level, such a differential is even more general. A number of the figures given, of course, are based on very few organizations.



Radar Harbor Installation

All shipping entering the harbor at Vancouver, British Columbia, must pass through a narrow channel about a mile long and about 400 yards wide. The Lions Gate Bridge passes over the outer end of the channel leading to the inner harbor and it is the radar installation on this bridge that is shown here. At the center of the bridge is a structure used as a signal station. It is in this signal station that the radar equipment is located. The two antennas shown are at opposite sides of the bridge, and are rotated in synchronism. This permits scanning of the area in the immediate vicinity of the bridge without shadows or blind spots. In addition to a short-range display of 3,000 yards, a long-range display of 15,000 yards is available. The radar equipment has been in use for approximately 400 hours, and has been chiefly employed to familiarize the staff of the signal station with the operation of the equipment.

Control System Synthesis by Root Locus Method

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THE ROOT LOCUS method solves the problem of finding the roots of the characteristic equation by an extension of concepts now associated with the frequency-response method. The roots describe the natural response of the system, and knowing them permits a solution for any input. Consider a simple single-loop system, shown in Figure 1, for convenience in developing a physical picture.

With the feedback loop open and a sinusoidal signal $e^{j\omega t}$ impressed at θ_σ, the feedback, θ_f, is a similar sinusoid shifted in phase angle and attenuated in amplitude as given by the open-loop transfer function $KG(\mathbf{s})=K_\mu G_\mu(\mathbf{s})\cdot K_\beta G_\beta(\mathbf{s})$ for $\mathbf{s}=j\omega$. If the frequency were of the value to cause a 180-degree phase shift and the gain K were then selected for unity amplitude ratio, closing the feedback loop would supply the error signal from the feedback signal so that a natural oscillation would be sustained. Lowering the gain would cause the oscillation to damp out, during which interval a damped sine wave $e^{-\sigma t}e^{j\omega t}$ must be propagating itself around the loop. An extension of the transfer function concept, admittedly not obvious, is that the phase shift and attenuation of such a damped sine wave from error to feedback is obtained simply by substituting the complex number $\mathbf{s}=-\sigma+j\omega$ into the function $KG(\mathbf{s})$. Thus one can find the natural response of the system by finding the values of $\mathbf{s}$ which make $KG(\mathbf{s})=-1$.

The graphical technique for computing this function is explained for the example by reference to Figure 2.

$$K_\mu G_\mu(\mathbf{s})=K(1+\tau_1\mathbf{s})(1+\tau_2\mathbf{s})\mathbf{s} \tag{1}$$

$$K_\beta G_\beta(\mathbf{s})=1 \tag{2}$$

The complex number $\mathbf{s}$ is itself a vector from the origin to a point which is pictured moving freely over the complex s plane. The phase angle of a vector $1+\tau_1\mathbf{s}$ is the same as that of the vector from the pole $-1/T_1$ to the s point; the amplitude is the ratio of line lengths from the pole to the s point and the origin respectively. The locus of roots is the path of values of $\mathbf{s}$ which make the total phase shift 180 degrees; a point on the locus is a root if gain is selected such that the amplitude ratio around the loop is unity.

Special parts of the locus such as intervals along the real axis and the point of crossing the $j\omega$ axis are found by inspection and the remainder of the locus then sketched. Note that the roots emerge from the open loop poles for zero loop gain and move out along the locus as indicated by the arrows as loop gain is increased. One usually selects the desired position of the dominant roots, r_1 and r_2 in this case, and then calculates the corresponding value of gain K. Knowing the roots permits the over-all transfer function of the system of Figure 1 to be expressed as:

$$\frac{\theta_0}{\theta_i}=\frac{1}{(1-\mathbf{s}/r_1)(1-\mathbf{s}/r_2)(1-\mathbf{s}/r_3)}$$

For each root r_i a term of the form $A_ie^{r_it}$ can exist in the transient response. For a step input the amplitude A_i is given by transform theory in a form which corresponds to a product of vectors from all other roots to the given root. Similarly, the over-all frequency response can be pictured as a product of vectors from all roots to points along the $j\omega$ axis. In a multiple loop system, the inner loop is solved first so that it may be replaced by a direct function.

Synthesis for a given control system can involve any one of four operations: selecting loop gain, changing given poles or zeroes, adding new poles or zeroes, or adding new loops. In the root locus method, these operations are achieved respectively by selecting the position of a root along a locus, changing the position of given poles or zeroes, adding new poles or zeroes, and sketching a new root locus plot. Other applications and development of the method are believed to be great. Thus the classic problem of finding the zeroes of n-th degree polynomial can be solved by successively combining two terms into one, using the root locus to find the values of the variable which make the ratio of the terms equal to -1. Multicoupled systems involve block diagrams in which intercoupling effects appear as signals being transmitted between loops. Such systems can be solved by isolation of loops or considering the effect of each coupling successively.

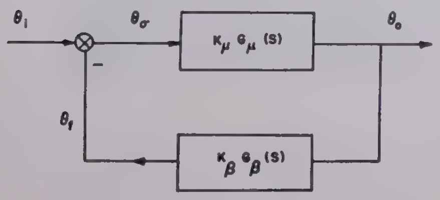

Figure 1. General block diagram of a single-loop system

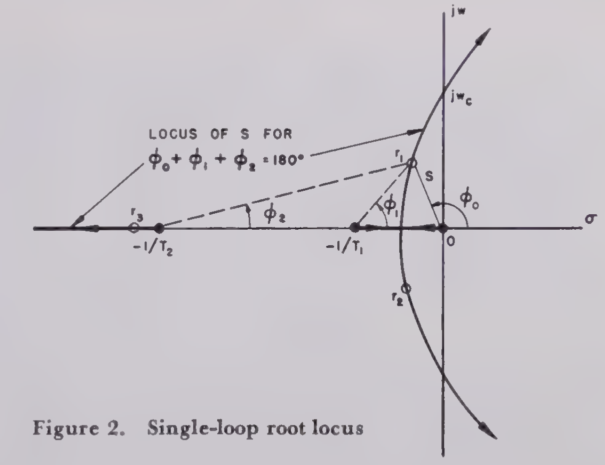

Figure 2. Single-loop root locus

Digest of paper **50-11,** "Control System Synthesis by the Root Locus Method," recommended by the AIEE Committee on Feedback Control Systems and approved by the AIEE Technical Program Committee for presentation at the AIEE Winter General Meeting, New York, N. Y., January 30–February 3, 1950. Scheduled for publication in AIEE *Transactions*, volume 69, 1950.

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Multiline Concentrator Apparatus

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Facsimile concentrator apparatus and telefax equipment has been installed in eight large cities. This article describes the main office equipment and demonstrates the operation of the new system for transmitting messages.

SINCE February 1949, the Western Union Telegraph Company has installed main office facsimile concentrator apparatus and associated patrons' telefax equipment in eight cities: Atlanta, Cincinnati, Dallas, Houston, Los Angeles, New York, Philadelphia, and San Francisco. Some 1,900 patrons, using the new Desk-Fax transceivers,[1,2] are connected to the nearest telegraph office. The multiline concentrator apparatus designed for this service consists of one or more concentrator operating tables (Figure 1) each with a 50-line turret, and one apparatus cabinet, located in a less busy section of the floor, for every two operating tables.

In addition to the main components of the concentrator table—the plug-and-jack turret, the transmitters and recorders—each table is equipped with four preamplifiers for the transmitters, two small ventilating blowers and canister-type filters for removal of any recording vapor, and a cabinet containing associated equipment. The cord shelf below the turret holds ten plug-ended cords; six at the left are connected with recorders and four at the right with transmitters. Signal lamps and push buttons on the shelf are associated with the operation of the respective units.

SIMPLIFIED VERTICAL TRANSMITTERS

To the right of the turret are four vertical drum transmitters, clip-connected and tiered to conserve space. Requirements of subject copy, operating procedures, ease of operation, minimum size, and low maintenance dictated the development of the vertical drum transmitter for this

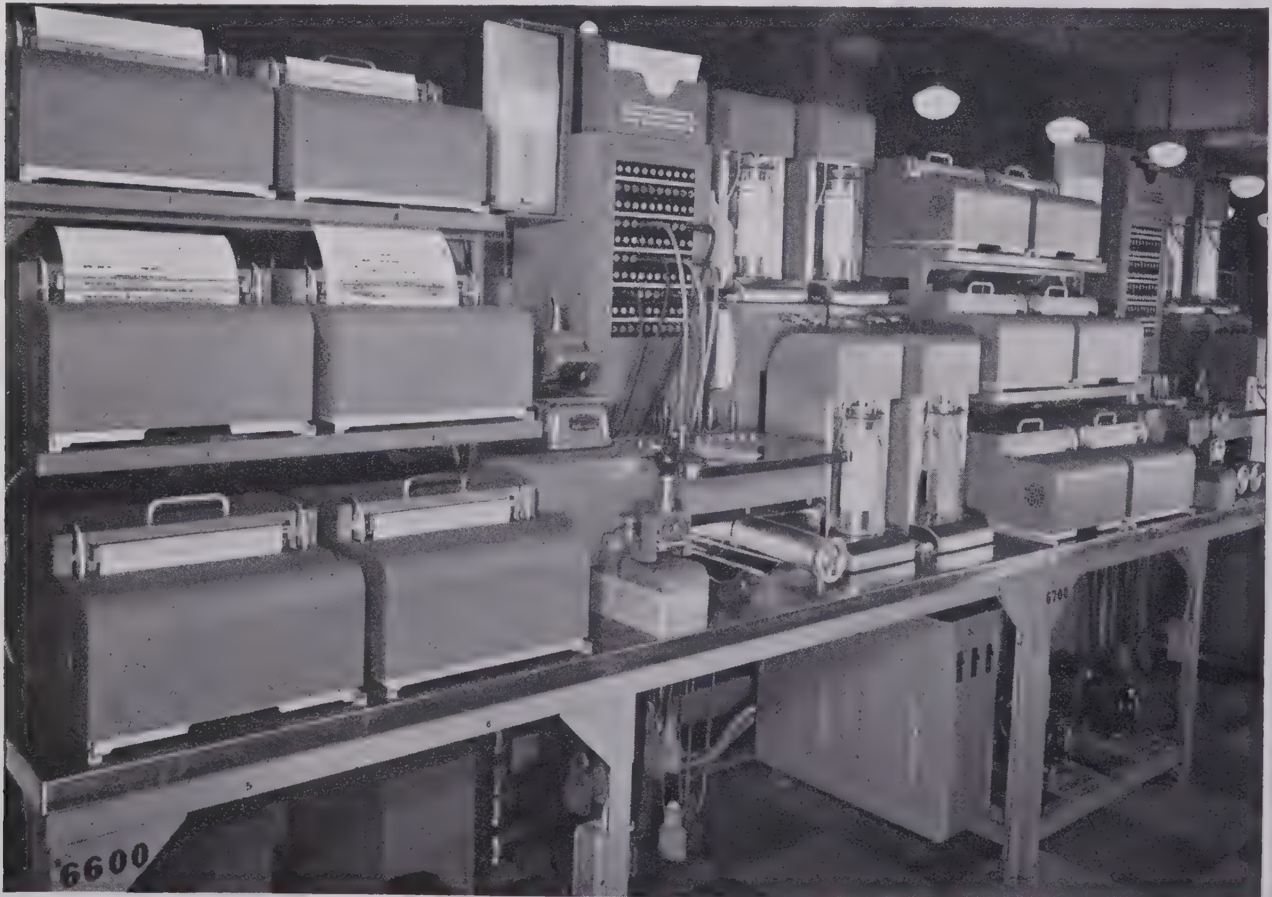

Figure 1. Two-table Desk-Fax concentrator installation at New York

Each table has a plug-and-jack turret, transmitters and recorders, preamplifiers, and ventilating equipment. The cord shelf has six plug-ended cords for the recorders and four for the transmitters as well as signal lamps and push buttons for each unit

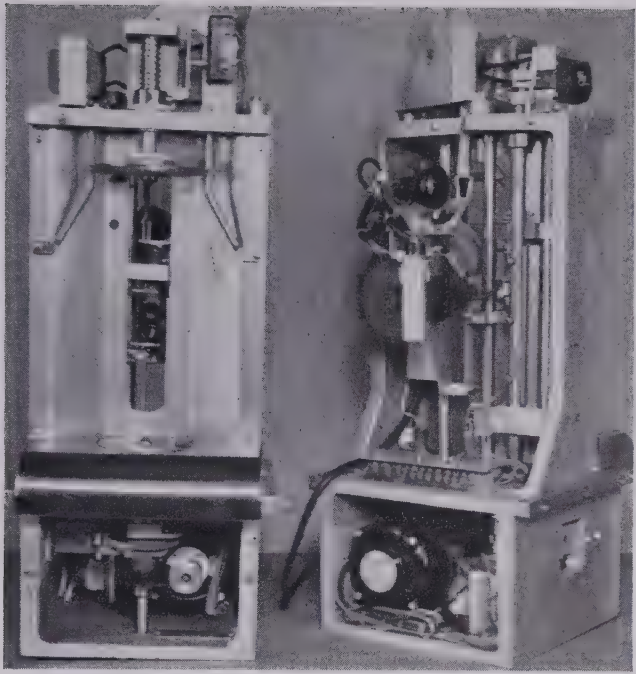

Figure 2. Front (left) and rear (right) views of telefax transmitter

The path of the light can be traced on the rear view from the source through the projection lens to the cylinder; from there it goes to the pickup lens and target, through the light chopper, to the photocell. The spring which returns the scanning carriage to its starting position is also shown on this view

service. Arranging the drum to rotate in a vertical rather than the usual horizontal position not only made possible the design of a machine having a base area of less than one-half square foot, but also afforded further space saving because a portion of the driving mechanism could occupy space beneath the top of the table. Another advantage the apparatus has is that the destination and identifying information on a message can be read by the operating clerk readily without removing it from the transmitter. She can handle the lightweight drum continuously without tiring and can insert it with one easy motion of either hand without looking at the machine—vital considerations where hundreds of telegrams per day are involved.

Telegrams are held on the drum by two movable toroidal spring bands, and provision is made for moving these bands so that they do not interfere with the scanning of the message. A band which is located near the bottom of a telegram in a transmitter is an indication to the clerk that the message has been scanned.

The transmitter (Figure 2) is assembled upon and within a narrow upright box-shaped aluminum casting. The scanning carriage feeds downward and is returned by a spring when released. The optical system is conventional, consisting of an exciter lamp-lens barrel assembly, pickup lens and target assembly, a "light chopper," which is a toothed wheel driven by a small motor, and a photocell which is connected to suitable amplifying and converting equipment. By using a photocell with the *S-4* cathode in combination with a tungsten filament lamp, it is possible to transmit not only black ink on white paper but also purple ink copy on buff paper with entirely acceptable fidelity.

THREE-STYLUS RECORDERS

To the left of each turret are six continuous recorders, (Figure 3), also tiered for compactness. This is a 3-stylus page-type recorder designed specially for the concentrator system to permit simple operating practices, such as ability to read incoming messages while being recorded, and the use of paper in roll form to eliminate individual insertion of receiving blanks. The recorder uses electrosensitive recording paper, a development of Western Union known as "Teledeltos."

Only two major assemblies are used in this instrument, a base plate including the paper-feed mechanism and a stylus drive assembly. A 4-watt synchronous motor, gear-coupled to the paper-feed roller, causes the paper to advance through the platen 0.01 inch for each scanning line, in this way giving 100 scanning lines for each inch of copy, and 14 square inches of recorded copy per minute.

Other unique features of the 3-stylus recorder include a hardened-steel grouping bar which the stylus bears against and rides on and which insures absolutely straight-line, uniformly-spaced scanning and the platen over which the paper passes, which is pivoted and spring-tensioned and is positioned so that the recording paper is in contact with the styluses at the scanning line but is clear of the return path of the styluses.

The stylus drive assembly (Figure 4) is a complete unit consisting of a casting mounting the motor which drives the stylus belt on which the three stylus holders are fastened.

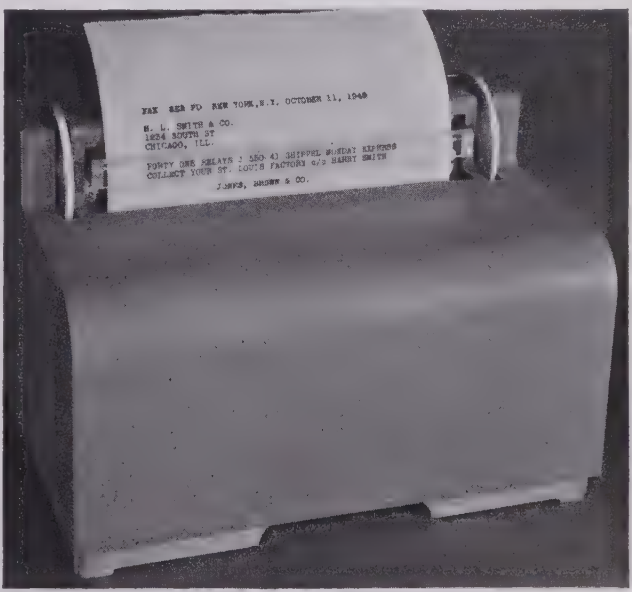

Figure 3. The 3-stylus fascimile recorder allows the incoming messages to be read while being recorded; the use of electrosensitive recording paper in a roll eliminates the need for insertion of individual receiving blanks. Six of these recorders, designed to permit simple operating practices, are tiered for compactness next to the turret as shown in Figure 1

Essentially full text of a conference paper, "Telegraph Office Desk-Fax Concentrator," presented at the AIEE Winter General Meeting, New York, N. Y., January 30–February 3, 1950.

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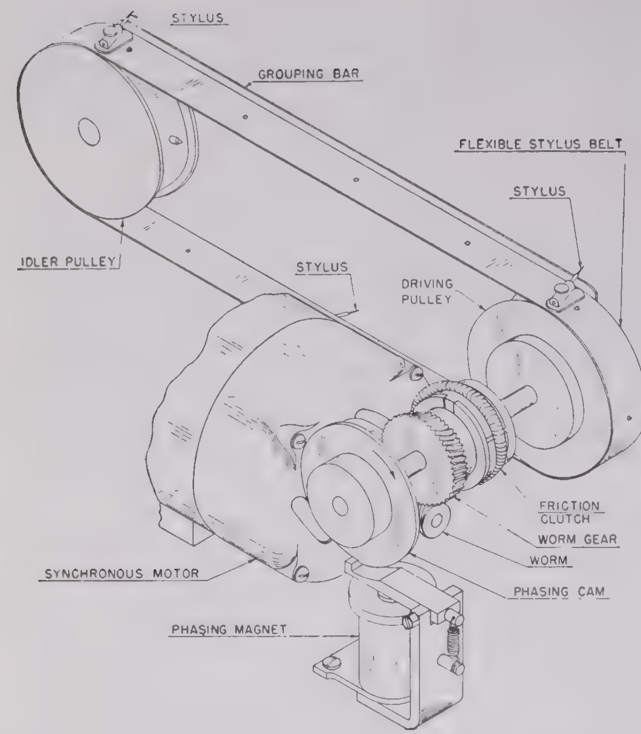

Figure 4. Stylus drive mechanism showing the synchronous motor which drives the stylus belt on which the three stylus holders are fastened

The stylus points which are of tungsten have a recording life of approximately 2,000 telegrams.

FUNCTIONING OF APPARATUS

Placing a drum in the transmitter at the operating position energizes two relays which ready the machine for transmission. The corresponding transmitter-cord plug is inserted into the appropriate patron's jack and the associated transmitter-start button is depressed. If the line is clear, the busy lamp lights on release of the transmitter-start button and a relay operates in the patron's unit causing its call buzzer to sound.

The patron acknowledges the call by loading his Desk-Fax transceiver with a Teledeltos blank and moving the start switch. This stops the patron's buzzer, powers the Desk-Fax, and automatically sets it up as a recording instrument as soon as the vacuum tubes are heated. A relay operates to energize the stylus-feed motor there and start the transmission of phasing pulses, which cause the main office transmitter to phase immediately, its carriage with photocell assembly to start the downward motion, and transmission of the telegram to proceed. After main office transmission is completed, an end-of-message lamp in the patron's Desk-Fax lights and the buzzer sounds, the patron shuts off the machine (or permits it to shut off automatically) and operates an "acknowledge" push button which extinguishes the end-of-message lamp, stops the buzzer, and interrupts the flow of direct current over the simplex loop. This causes the busy lamp at the concentrator position in the main office to be extinguished and the acknowledge lamp to light, thus informing the clerk that the telegram has been received. Removal of the transmitter-cord plug from the jack restores the line to the stand-by condition, and removal of the drum releases the power relays and completes the transmitting cycle, leaving the transmitter in its normal standby condition.

When a Desk-Fax transceiver is turned on for sending, a line relay in the concentrator cabinet at the main office lights the call-in lamp in the turret above the jack associated with the patron as well as the common signal lamp at the top of the turret. Insertion of a recorder-cord plug into the jack causes the line relay to release and extinguishes both call-in lamps. Depressing the associated recorder-start button operates two power relays, one in the table and one in the equipment cabinet. The first operates the red busy lamp and energizes the stylus motor of the recorder which readies it for recording; the power relay in the cabinet energizes the recording amplifier.

A relay in the patron's Desk-Fax operates to start the transmission of phasing pulses which cause the main office recorder to phase, and starts the stylus-feed motor of both the Desk-Fax and main office recorder. Transmission from the patron's transceiver continues until the machine shuts down automatically or until the start-stop switch there is operated manually. When this happens, transmission of the phasing pulses ceases, operating a control relay at the concentrator position in the main office, which in turn lights the end-of-message lamp on the cord shelf and interrupts the operating circuits for both power relays. Release of the relays removes power from the recording amplifier and the stylus- and paper-feed motors of the recorder and extinguishes the red busy lamp.

When the end-of-message lamp lights, the clerk manually feeds out a conventional telegram blank length of paper, which causes the end-of-message lamp to be extinguished and restores the last of the control relays to its normal position. Disconnection of the recorder plug and cord restores the line to the normal stand-by position.

In the facsimile system described, the patrons' Desk-Fax units and main office concentrator equipment are powered with synchronous a-c motors to operate from a common 60-cycle 115-volt a-c power source. Desk-Fax installations must be confined at present to locations mutually served by one a-c power source, although provisions are under development for operating in d-c areas and from separately synchronized a-c power systems.

The line facility should be a quiet transposed pair, the two wires of which should have approximately the same ohmic resistance, as simplex control circuits are superimposed on the pair. Transmission levels from the patron's unit and the main office transmitter are limited to five decibels above one milliwatt to avoid the possibility of cross-talk, and 25 decibels at 2,500 cycles is the maximum allowable line attenuation. These requirements permit Desk-Fax operation over $5^1/_2$ wire miles when 26-gauge high-capacity cable is used, and over approximately 14 wire miles when the heavier 19-gauge high-capacity cable is employed.

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Speed-Torque Control of Induction Motors

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A MATHEMATICAL analysis was made to determine the effect of symmetrical series reactance in the supply lines upon the speed–torque relation, the power factor, and the efficiency of standard induction motors. The analysis showed that torque, the speed for pull-out torque, and the power factor are functions of the added reactance. The efficiency, however, is a function of the machine constants and speed only, and is, therefore, not affected by the added reactance. The nature of the speed–torque and power-factor variation is as follows, if the supply voltage is assumed constant. The expression for the speed at pull-out is actually an expression for impedance match between stator and rotor. The addition of a small series capacitive reactance into each phase reduces the impedance of the machine, thus increasing the current and also the torque. The impedance match between the windings, however, occurs at a lower speed, thus reducing the speed for pull-out. Addition of more capacitive reactance depresses the speed for pull-out and increases the magnitude of pull-out torque until a critical value of series reactance is reached. At this critical value, series resonance and pull-out occur at the same speed, and the impedance match for pull-out becomes a resistance match. Therefore, this critical value of series reactance determines the maximum value of pull-out torque that can be obtained from the machine at constant voltage. Furthermore, the speed for pull-out has been reduced to its minimum value, since it is limited by the ratio of rotor to stator resistance.

Further increase in the series capacitive reactance makes the input impedance to the network capacitive at speeds below series resonance, and series resonance now occurs at speeds greater than pull-out. Thus the speed for pull-out is increased and the magnitude of pull-out torque is decreased when the series capacitive reactance exceeds the critical value. Series resonance, that is, unity power factor, now occurs at a speed very nearly that for rated torque, and it is clear that this is the most desirable range of reactive speed control. Series reactive speed control should be combined with voltage control to limit the current if pull-out occurs at very low speeds.

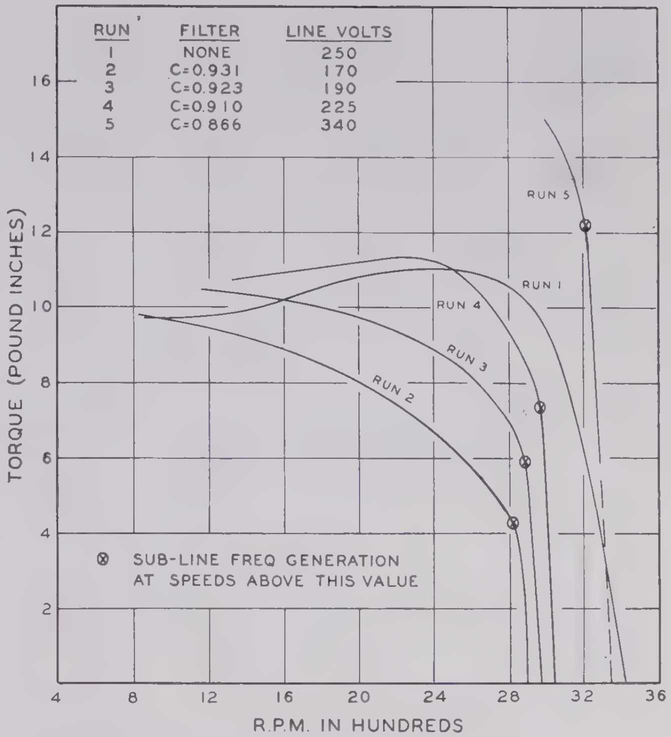

Figure 1. Reactive speed–torque control of 3-phase 4-pole 1-horsepower induction motor at 120 cycles per second (General Electric Model *5K203D17*—modified rotor)

The insertion of series capacitive reactance has another important effect upon the performance of the machine. There now exists a system natural frequency determined by the capacitance and the effective input inductance to the motor. With the values of capacitance used for most effective speed control, this natural frequency is always less than line frequency. When the machine is brought up to a speed corresponding to synchronism for this sub-line frequency, this frequency is generated quite independently of the supply frequency, and the unloaded motor runs at a speed determined by equality of the generator and motor torques. For pure series capacitance the speed at which this phenomenon occurs is, in general, below pull-out torque. If a parallel inductance capacitance filter is used to obtain the desired value of reactance at line frequency, the speed for generation of sub-line frequencies is determined by the antiresonant frequency of the filter, since the filter is inductive below antiresonance. Thus, a means is provided for controlling the speed at which sub-line frequency generation begins. The phenomenon is used to give improved speed regulation at low speeds.

The analysis was verified by tests, one of which is illustrated in Figure 1. Run *1* represents the normal operation of the motor, with no series filter. Run *2* is very nearly the critical case where pull-out occurs at minimum speed. Here the induction motor has very nearly d-c series motor characteristics. Runs *3*, *4*, and *5* represent values of capacitive reactance greater than critical; here the speed for pull-out torque can be raised above that for the normal motor. For Runs *3*, *4*, and *5*, unity power factor occurs at speeds slightly below the speed at which sub-line frequency generation begins.

Digest of paper **49-239**, "Reactive Speed-Torque Control of Squirrel-Cage Induction Motors," recommended by the AIEE Rotating Machinery Committee and approved by the AIEE Technical Program Committee for presentation at the AIEE Fall General Meeting, Cincinnati, Ohio, October 17–21, 1949. Not scheduled for publication in AIEE *Transactions*.

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A New Transmission-Line Suspension Clamp

SVERRE SANDBERG

A DEVICE for suspending power-line cables at the insulators must be satisfactory from the point of view of the stresses produced. The more acute bends at the points of suspension will obviously result in greater bending stresses in the cable there than in the free span between them. This bending stress is also increased by the tensional stress in the cable. Quite gentle winds, moreover, may easily set up vibrations in the cable, which will increase the stresses at the points of suspension to such an extent that the cables will break after a longer or shorter period. The efforts to reduce this drawback were at first directed wholly to reducing the effect of cable vibrations while disregarding the necessity of diminishing the much larger and more dangerous bending stresses.

In order to explain more fully the principles of the new suspension clamp of the Svenska Aluminiumkompaniet, this article will present the formulas and the graphic method which has been developed and used for determining a suitable radius of curvature for the conductor seat in a clamp for supporting a conductor, and also of the required length of the clamp.

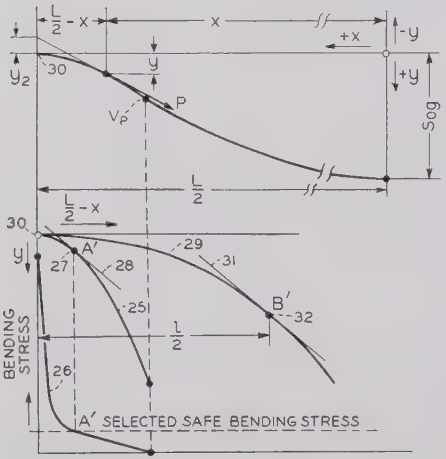

Figure 1. Graphic method for the determination of bending stress, curvature, and length of clamp

The bending stress δ in a conductor may be calculated from the known formula

$$\delta=\frac{1}{R}E\frac{d}{2} \tag{1}$$

The sum of the bending stress and the tensional stress in the conductor must not at any point exceed a value corresponding to the selected safety factor under vibration. For a conductor containing strands of aluminum, we have selected a bending stress $\delta=4{,}267$ pounds per square inch.

From the selected value of δ, the radius of curvature R of the cable groove may be determined with the aid of equation 1. Referring to Figure 1 the elastic line of the conductor may be determined by

$$y=\frac{gL}{2c^2}\left(\frac{L}{2}-x\right)+\frac{gLk}{2c^3}\left(e^{-\frac{C}{K}\left(\frac{L}{2}-x\right)}-1\right) \tag{2}$$

and the bending stress by

$$\delta=\frac{gL}{2ck}\left(-\frac{2k}{cL}+e^{-\frac{C}{K}\left(\frac{L}{2}-x\right)}\right)E\frac{d}{2} \tag{3}$$

where

R represents the radius of curvature of the conductor at the investigated point.
g represents the acceleration due to gravity.
L is the length of span.
$c^2=\frac{P}{\rho}$
P represents the tension in the cable.
ρ represents the mass of the cable per unit length.
$K^2=\frac{EI}{\rho}$
E represents the modulus of elasticity.
I is the sum of the moments of inertia for the individual wires of which the cable is composed.

The important fact is established that the natural "amortization" of the bending stresses, which a freely hanging conductor chooses, is highly unfavorable for the material. Furthermore, it is settled that the conductor is strained beyond the elastic limit, only because of the bending stress from sagging. It is necessary that the conductors are supported and clamped in such a way that these bending stresses are brought down to a safe value by means of a proper design of the suspension clamp.

The astounding fact that has been established by this investigation is that the reason for the breakages of transmission line conductors "due to vibrations" is not primarily the vibration. In fact, the reason lies in the clamp itself.

In order to find out the vibration damping effect of the clamp, tests were made at the experimenting station of the Swedish Royal Board of Waterfalls. Conductor "Hawk" was strung with 8,500 pounds per square inch at 60 degrees Fahrenheit. The recorder gave direct registrations of the vibrations on a paper roll. The vibration period could be changed between 15 and 28 periods per second. The results show 80 registrations during the forced vibrations. The minimum reduction of amplitude, measured on the conductor, 32 inches from center of clamp, at 16 periods per second, was 35 per cent. With higher periods, the reduction increased.

Digest of paper **49-287**, "New Suspension Clamp for Transmission-Line Conductors," recommended by the AIEE Transmission and Distribution Committee and approved by the AIEE Technical Program Committee for presentation at the AIEE Fall General Meeting, Cincinnati, Ohio, October 17–21, 1949. Not scheduled for publication in AIEE *Transactions*.

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The Electronic Servomechanism Simulator

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A LARGE-SCALE analogue computer, capable of solving the general equations of motion of an aircraft, to be used primarily in the development of aircraft control systems is being developed at the Massachusetts Institute of Technology. The electronic servomechanism simulator is included as a portion of the computer to represent electrically the dynamic behavior of the servomechanisms which position the aircraft control surfaces. These servomechanisms usually are designed to operate linearly. However, a servomechanism which is small enough to be practical occasionally will be required to operate at the extreme limits of its physical capacity—beyond its linear range.

Although the exact nature of the nonlinearities to be expected depends upon the particular servomechanism employed, certain types of nonlinearities are fairly common. For example, the control-surface deflection usually is limited either by external limit stops or by the limited stroke of the power output device itself, as in a hydraulic ram. When the servomechanism is clutch-powered the output velocity is limited to a value corresponding to the speed at which the clutch is driven. Amplifier overloading and magnetic saturation in electric motors often cause nonlinear operation.

Any two systems, whether electric, mechanical, hydraulic, or thermal, may be said to be analogous when there exists a definite parallelism in the form of the mathematical relations representing them. Electronic simulation of a system involves the identification of an analogous electronic element with each portion of the given system to be represented explicitly. Logically, then, the simulation of a specific system should begin with an analysis of the system components in mathematical terms and proceed through the medium of mathematics to the synthesis of a suitable analogue.

The application of such a procedure to the elementary servomechanism represented schematically in Figure 1 results in the analogue shown in Figure 2. This servomechanism comprises a motor K_m which drives a load composed of the inertia J_m and the viscous damping B_m. The output displacement of the servomechanism is limited by stops placed at the positions $+\theta_s$ and $-\theta_s$. Representation of the linear behavior of the servomechanism requires a summing circuit (number 1 in Figure 2), an amplifier with a gain K_m, a simple resistance-capacitance network with a time constant $RC = J_m/B_m$, and an electronic integrator with an integrating factor of $-1/B_m$. The limitation on the output of the analogue is achieved by feeding back a voltage proportional to the torque τ_s exerted by the limit stop on the output shaft of the servomechanism. The overshoot ϕ, defined in the caption of Figure 1, is generated by the network of resistors and diodes; a special circuit G_s then forms from this quantity the torque τ_s. This method of limiting the output dissipates the energy of the system in a manner analogous to the way kinetic energy is absorbed when the output of a servomechanism is stopped abruptly by limits. By limiting the voltage across the network capacitor, as indicated in Figure 2, it is possible to simulate a maximum motor velocity as well.

The synthesis procedures already described indicate analogues which require the following electric computing elements for representing the linear characteristics of a system: summing circuits, voltage amplifiers, integrators, and passive networks composed of resistance, capacitance, and inductance. A study of several basic servomechanisms, moreover, indicates that the most important nonlinearities in these systems can be represented with reasonable accuracy by the addition of voltage limiters and a special displacement-limiting circuit.

The stability and accuracy of these units are of such values that linear mathematical functions of reasonable complexity can be represented with errors not exceeding one per cent.

Digest of paper **50-47**, "An Electronic Simulator for Nonlinear Servomechanisms," recommended by the AIEE Committee on Computing Devices and approved by the AIEE Technical Program Committee for presentation at the AIEE Winter General Meeting, New York, N. Y., January 30–February 3, 1950. Scheduled for publication in AIEE *Transactions*, volume 69, 1950.

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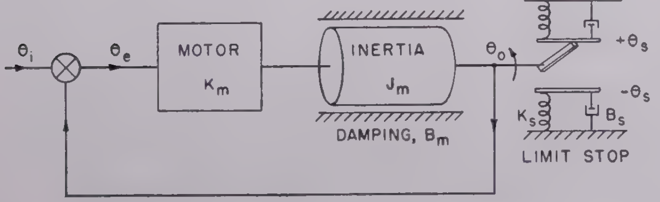

Figure 1 (left). Elementary servomechanism with displacement limited

$$\theta_e=\theta_1-\theta_0;\ \tau_m=k_m\theta_e;\ J_m\frac{d^2\theta_0}{dt^2}+\frac{B_m d\theta_0}{dt}=\tau_m-\tau_s;\ s=\frac{B_s d\phi}{dt}-K_s\phi=G\phi_s$$

$\phi=0$ when $-\theta_s < \theta_0+\theta_s$; $\phi=\theta_0-\theta_s$ when $\theta_0 \geqq +\theta_s$; $\phi=\theta_0+\theta_s$ when $\theta_0 \leqq -\theta_s$

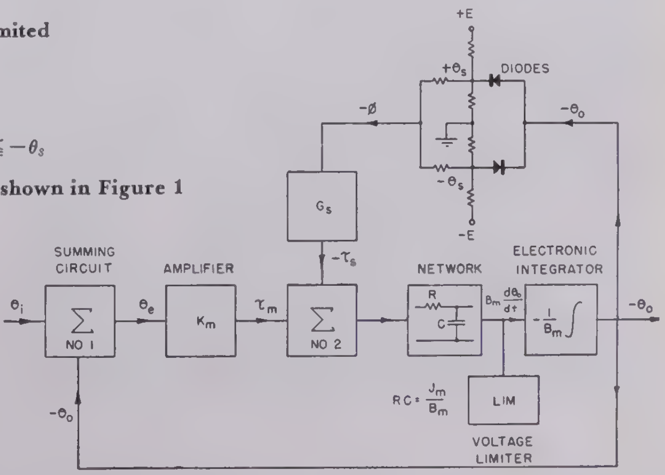

Figure 2 (right). Analogue of the elementary servomechanism shown in Figure 1

Safety in Substation Design

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Accident prevention in a substation begins at the drafting board. Educating personnel is only a partial safeguard against mishaps. The elimination of shock hazards is best accomplished by incorporating safety features in substation design. Proper clearances and illumination, accessibility to equipment, adequate grounding, and allowance for future growth are some of the features that should be provided.

IT CANNOT be emphasized too strongly that safety must be designed into substation structures and equipment installations. It is believed that many tragic accidents which have occurred in substations had their inception when unnecessary hazards were built into the stations. The combination of an unsafe condition and an unsafe act usually results in a personal injury and is generally recorded as a careless act on the part of the injured. Investigations have revealed many contributing factors in the occurrence of accidents.

The actual design of the substation is determined by numerous conditions. The importance of the station determines whether it shall be a simple, cheaply constructed, small structure with fused circuits or a more elaborate layout with double bus, oil circuit breakers, by-pass arrangements, and intricate relaying. Long-range planning may call for a major substation at some particular site, but, at the moment, only a simple arrangement which may be a temporary structure or a design that can be enlarged. Unfortunately, many temporary structures become more or less permanent. Regardless of whether the structure is to be permanent or temporary, if sufficient thought is given to accident prevention, unnecessary hazardous conditions can be avoided without materially increasing the original cost.

It is generally advisable to use some standard layout, that is, a design which has been tried and proved and incorporates all of the safety factors. A well-designed substation inherently will be a safe substation. There are, however, a few details that can be added to make it safer, thereby minimizing the exposure to unrecognized hazards.

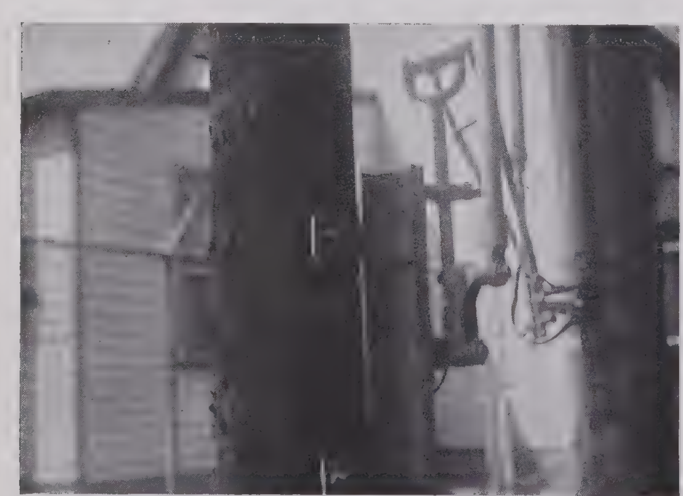

Figure 1. A man was electrocuted opening this group disconnecting switch

DESIGN FOR SAFETY

Establish Proper Height. From observation, a common fallacy is to establish the height of a station and design to this height. In many cases, this results in close quarters, and a lack of head and elbow room. The height should be incidental to a good design and should be established by working from the "ground up" instead of from the "sky down."

While most major equipment is now designed to meet safety recommendations, particular attention should be given to obtaining the proper height of the live parts above the ground, with suitable foundations or supports. Adequate phase and ground clearances should be maintained throughout, with particular attention to location of switches and fuses with respect to both the operator's safety and the operation of the equipment. In other words, provide both head and elbow room.

Provide for Changes. Provision should be made for the removal of large equipment and for future additions. These points are often neglected because many substations are designed for immediate use with the idea that they never will grow. Actually, this is seldom the case; experience has proved that most substations will be required to expand at some time.

With the development of new switching arrangements, it becomes more and more important that each switching operation be understood thoroughly by all those involved.

Fence Insufficient Protection. Another common fallacy is that a fence, with a locked gate, around the substation is all that is necessary for safety. Statements are frequently made that when a man is permitted to enter the substation yard, it is because he is well-qualified and knows what it is all about; therefore, additional barricades or protective measures are a waste of time and money. Accident records defy this philosophy, because it is the experienced and well-qualified men who generally are involved in substation tragedies.

Essentially full text of **49-274,** "Safety in Substation Design," recommended by the AIEE Committee on Substations and approved by the AIEE Technical Program Committee for presentation at the AIEE Fall General Meeting, Cincinnati, Ohio, October 17–21, 1949. Not scheduled for publication in AIEE *Transactions.*

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FACTORS IN ACCIDENTS

In order to develop a long range "no accident record," all of the contributing factors in past accidents must be taken into consideration. It should be recognized that the injury to a person is only the spectacular evidence of an accident, the outward sign of something gone wrong.

Regarding these things that have gone wrong, it should be emphasized at this point that there is no intention to minimize the individual workman's or foreman's responsibility for accidents which have been commonly classified as carelessness. However, it has been established that there are other factors involved in accidents which cause serious or fatal injuries to substation workmen.

Safety engineers have seen a great many questionable conditions within substation enclosures wherein it would be necessary to watch every step one made in order not to get into any trouble. Some of the conditions referred to are as follows:

1. High-voltage lightning arresters installed on pedestals, ranging from 5 inches to 2 feet in height, with no protecting barricades.

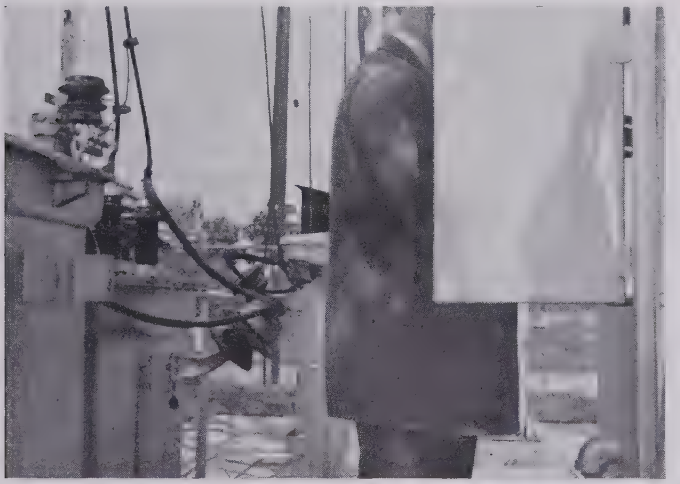

Figure 2. Actual location of 13.2-kv contact

2. Busses of various voltages, ranging from three feet to six feet in height from the ground.
3. Transformer leads, both high and low voltage, strung out like spider webs, the height of the leads and busses being determined only by the height of the transformers.
4. Hazardous location of high-voltage and other fuses.
5. Neglecting to install fixed barriers in congested arrangements.
6. Equipment grounds inadequate.

As an example, a visit was made to a 13,200-volt substation and it was apparent that the structure was designed from the "sky down," and that supporting members were installed before obtaining the dimensions of the transformer bank. At one point, the 13,200-volt transformer lead was within a few inches of an airbreak switch control handle. Should the operator not be conscious of this condition and not always on guard, or should he slip, another so-called careless accident would result.

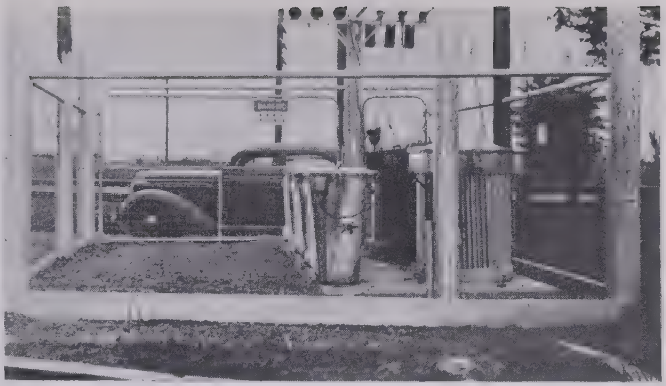

Figure 3. Low leads caused electrocution in this substation

In another case, investigation of an actual fatal accident revealed that a substation operator was electrocuted while attempting to open a 44,000-volt gang-operated disconnecting switch. A flashover occurred as the switch was being opened, resulting in energizing the operating mechanism, and an arc was established between the man's chest and the switch handle. Later ground resistance tests of the switch handle showed 100 ohms. Other grounds within the same station were as low as two ohms. It is essential to provide adequate protection for switch operators. See Figure 1, scene of the accident.

A third case worthy of mention is a situation resulting from an addition made to an existing substation. This involved the installation of two small transformer banks together with feeder regulators. The transformers merely were placed upon the existing concrete pad at a predetermined location and wired from the "sky down." At a later date, it became necessary to work on the mechanism of an automatic reclosing 66-kv circuit breaker. This work was being performed by two qualified and experienced men, but before it was completed, one employee (with the rank of supervisor) backed into a 13,000-volt connection. See Figure 2.

Engineering for safety has been apparent in the construction of a great many large stations in recent years. However, quite frequently safety is neglected in the design and construction of the smaller type of substations and rural structures. This often results in the creation of unnecessary hazardous conditions.

ANALYSIS OF SUBSTATION ACCIDENTS

The Edison Electric Institute Accident Prevention Committee's report for the year 1947 describes 173 fatal accidents which occurred within the electric light and power industry. Of this number, 72.3 per cent were electric shock and burn cases and 25.6 per cent of these fatalities took place in stations on or around equipment and bus structures.

A tabulation of accidents compiled by the authors of this article (Table I) briefly indicates the hazards involved with regard to the accidents and the corrective action necessary to have avoided them and to preclude recurrences of similar mishaps. Carelessness was omitted from the correction column intentionally, because it is believed that this is controllable through proper training and supervision.

It can be seen from this analysis that if proper thought had been given to safety, that is, accident prevention, many of these accidents would not have occurred because the hazardous conditions would not have existed or they would have been eliminated. Also, the need of supervisors to develop safe operating procedures is evidenced.

Included in the tabulation is another specific example of the "behind-the-scene" cause of accidents. A small 11,000- to 2,300-volt distribution substation, involving two banks of transformers, was installed. The height of these transformers was between four and five feet. The bushings on both high- and low-voltage sides were of the pocket type. The transformers were installed upon a low concrete pad and from then on it was just a plain "wiring" job without any thought of future safety. A fence was installed around the substation and within a week after the station was energized, a workman was delegated to clean up. While he was intent upon what he was doing, he backed into an 11,000-volt energized lead—death resulted. This unnecessary tragedy would not have occurred if the station had been designed originally to provide adequate clearance. See Figure 3.

MODEL SUBSTATION

In order to develop a more comprehensive understanding of the meaning of accident prevention, a model substation was built for the purpose of demonstrating, in an educational way, how accidents involving experienced men have occurred.

The scale model substation, shown in Figures 4 and 5, is a replica of several which actually have been installed. This particular model represents a 34.5-kv switching station having main and transfer busses, using a scale of three-fourths

Table I. Analysis of Fatal Substation Accidents

Occupation	Age	The Job	Contact Voltage	Hazard	Correction
Substation operator	55	Open group disconnect	44,000	Unsafe practice	Training; provide adequate protection (engineering)
Lineman	32	Replace high-voltage fuses	33,000	Unsafe practice	Enforce switching, tagging, and grounding procedure; structural changes required
Lineman	38	Revamp 13.2/2.3-kv small substation	2,300	Work being performed without de-energizing low-voltage feed back	Proper planning; close supervision
Electrical foreman	48	New construction	13,200	Insufficient working clearance to live parts	Use of portable insulated barricades
Four cases		Two—obtaining name-plate data Two—cleaning	13,200 to 33,000	Personal; lack of knowledge	Use of warning signs; training
Two cases		Painting	13,200	Live parts inadequately barricaded	Supervision; proper planning
Lineman	31	Phasing out new transformer station	2,300	Unsafe practice	Proper clearance procedure; supervision
District serviceman	53	Installing maximeter, 2,300 volts	22,000	Unsafe practice	Safe operation in substations regarding clearances, protection, barricades, tagging, grounding, and so forth
Lineman	33	Installing overhead circuit in substation yard	2,300	Unsafe practice and misunderstanding	Ground circuits worked as dead; explicit instructions will avoid misunderstandings
Lineman	37	Adjusting and repairing 33-kv automatic airbreak switch	33,000 (due to control transformer feedback)	Safety rule violation	Tagging and grounding; guard against feedback—potential and control transformer
Lineman	39	Refusing 13,200-volt transformer bank	13,200	Climbing structure without proper clearance	Enforcement of switching, tagging and grounding rules
Electrician	33	Cleaning	11,000	Low leads	Proper engineering and construction
Electrician		Maintenance	11,000	Unsafe conditions	
Electrical superintendent	39	Relay repair	13,200		
Laborer	42	Cut grass	11,000		
Lineman	33	Sweep transformer pad	11,000		
Electrician	48	Replace switch numbers	33,000	Climbed structure in wrong bay	Rope off bays and apparatus adjacent to working area
Electrician	39	Repair "dead" disconnect	33,000		
Electrical construction	43	Repair "dead" control transformer	33,000	Attempted to work on wrong transformer	
Painter	54	Paint potential transformer	33,000		
Electrician		Repair disconnect	110,000	Work on switch with one side "alive"	Proper supervision; proper clearance procedure
Electrician	42	Repair disconnect	33,000		
Electrician	34	Change oil circuit breaker bushing	11,000		
Lineman	33	Disconnect "dead" lightning arrester	13,200	Inadequate clearance	Proper engineering and construction; use of insulated barricades
Electrician	36	Paint structure	33,000		
Electrician	26	Repair switch	33,000		
Electrical foreman	45	Install control-transformer steel structure	4,600	Location too dangerous to work with bus alive	Proper engineering; proper planning
Electrician	56	Clean control-transformer bushing	22,000	Unsafe practice	Enforcement of proper switching, tagging and grounding procedure
Assistant line foreman	42	Replace bolts and adjust disconnects	66,000	Working too close to 66-kv live parts	Use qualified men; proper supervision; use of insulated barricades necessary to safety
Electrician's helper	37	Repair carrier current cap	66,000	Unsafe practice	Proper supervision; enforcement of strict tagging and grounding procedures
Substation operator	77	Operate switches	11,000	Unsafe conditions	Install proper switch designation; install barriers between circuits
Lineman	28	Make connection to live bus	2,300	Unsafe practice	Proper planning; proper supervision
Supervisor of electrical maintenance	53	Replace bolts in "dead" copper tubing clamp	33,000	Unsafe practice; work too close to live parts	Prohibit work being performed in close proximity to live parts which cannot be barricaded or otherwise isolated
Lineman	30	Replace air-break switch insulators	44,000	Unsafe practice	Proper planning; enforce switching, tagging, and grounding procedure
Electrician	32	Paint lightning arresters	33,000	Protection procedure violated; chance taking	Proper supervision
Electrician	33	Overhead construction work in "dead" bay	33,000	Usual	Complete safety supervision
Painter	44	Repaint oil circuit breaker and cell structure	11,000	Unsafe method	Proper supervision; use of temporary barricades
Lineman	39	Replacing transformer fuse in substation	13,200	Unsafe practice and unsafe condition	Enforcement of proper procedure; correct unsafe structures

inch to the foot. All members are made of wood, the columns and beams being grooved to represent 6-inch *H*-members. The channels and angles were left square in order to provide strength. The absence of the true shape of these members in no way detracts from the structure. Quick-drying model airplane glue was used on all the joints of the structure.

All bushings, bus supports, and strain insulators are made to scale and turned from a wood dowel. The disconnecting switches and air-break switches are made of brass and copper and can be operated to demonstrate switching procedures. The main and auxiliary busses are made of one-eighth inch welding rod, bronzed to represent copper tubing. The balance of bus connections and taps are made of Number *10* solid copper. The oil circuit breaker, complete with bushings, framework, and mechanism housings, is scaled from a 34.5-kv breaker. The *T* and straight connectors are made of wood with a hole drilled for obtaining the necessary close fit for the bus connections.

Other items used in the training program are portable grounding devices, extension and step ladders built to scale and portable scaffold for substation maintenance work. Figure 4 shows an exhibit of one of the problems, that is, complete switching, tagging, grounding and roping off of work areas for a job representing oil circuit breaker bushing replacement.

Many demonstrations and discussions, with the use of the model, have revealed these thoughts and opinions in the interest of safety in substations:

1. Showing how electric contact accidents have occurred in substations is an effective means of revealing bad habits.

2. The necessity of providing adequate head and elbow room when designing substation structures.

3. Points out the reasons for providing adequate protection for switching operators.

4. Visual demonstration of when and how to use portable barricades and the roping off of working areas is very effective.

5. Frequently hazards are not recognized as such.

6. Many times the hazards are recognized but are not guarded against except by word of mouth.

7. Problems and questions in proper switching, tagging, and grounding procedures can be set up. That is, actually showing by demonstration the correct interpretation of "mark-up" or "tagging rules."

8. The model substation is a valuable means of training new men in regard to safe operating procedures.

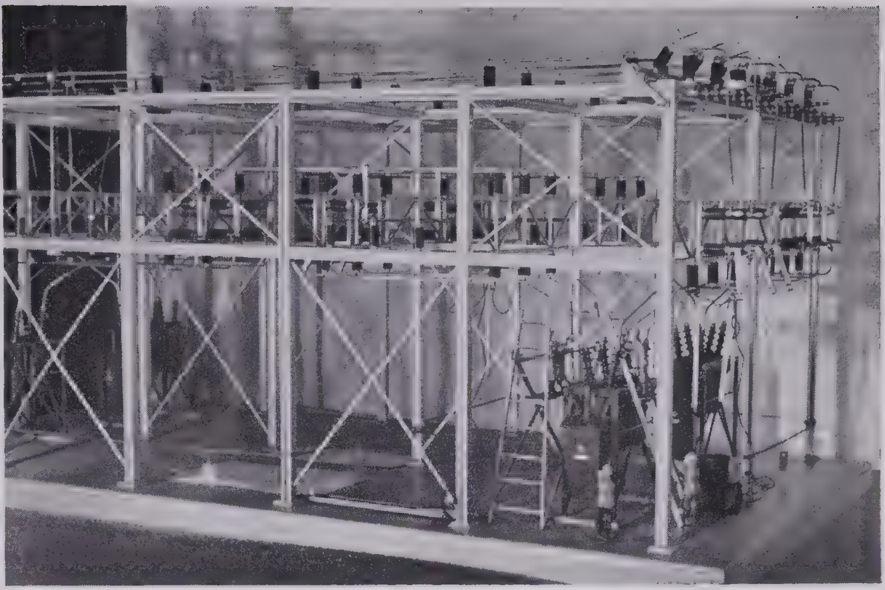

Figure 4. A 34.5-kv scale model switching station (3/4 inch to the foot)

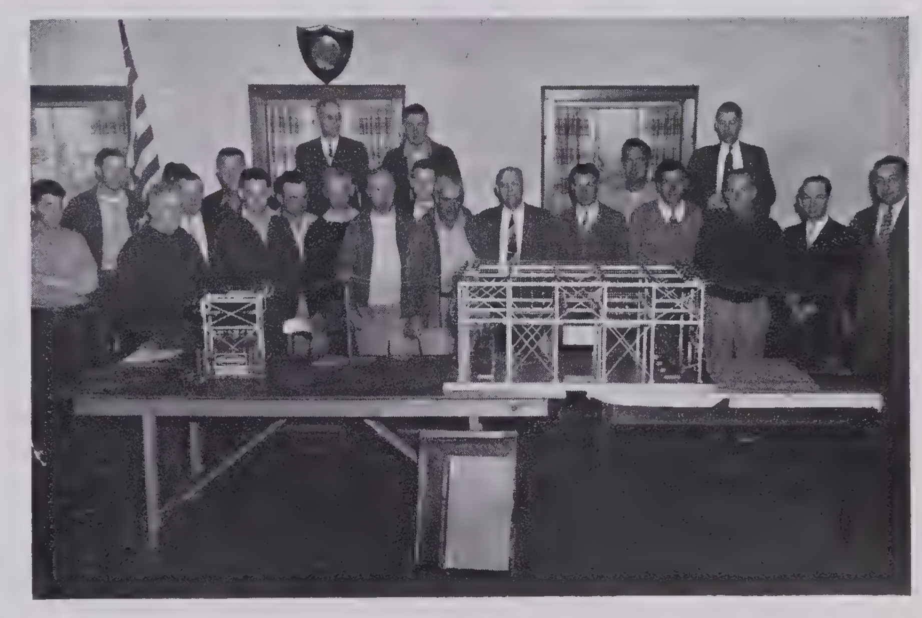

Figure 5. Safety demonstration with scale model switching station

CONCLUSIONS

Accident prevention in a substation starts by providing proper clearances, simplicity in design, accessibility, proper illumination, and extreme care in the development of adequate grounding. To be brief, safety begins on the drafting board.

A review of the records will show that much has been achieved recently in the prevention of employee accidents. Yet, in spite of the splendid progress made there is still a great deal to be accomplished. In this article an attempt has been made to emphasize the very important role of design engineers in the work of preventing unnecessary human injury and destruction in the substations of electric power systems.

66-Kv Switching and Transformer Stations

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IN THE DEVELOPMENT of standard patterns for switching and transformer stations for the 66-kv system of the Pennsylvania Power and Light Company full recognition was given to the interdependence of other standard patterns for general system development.

On this system 220 kv is used only for bulk transmission of power. The 66 kv is used not only for transmission but also for distribution to larger customers. General distribution primary voltages are 12 kv and 4 kv. Voltage is controlled on the entire system by the use of generators, synchronous condensers, and dispersed capacitors, automatically switched. The reliability of the various parts of the system are carefully correlated to avoid providing unnecessary facilities. In particular, advantage is taken of increased reliability of transmission lines by serving important loads from a single circuit of considerable length through rugged terrains.

Substations on the 66-kv network of this system perform two principal functions. One of these, arising out of the operation of the 66-kv system as a network, is the switching of circuits; the other is the transforming of power from one voltage level to another. These two functions can be and are performed independently of each other. That is, a reliable moderate-capacity transformer substation may be installed without a switching station for the primary supply lines. Conversely, a switching center for network lines may be completely separate from step-down transformers.

It has been found that the requirements of the entire range of conditions encountered on this system can be met with five basic layouts shown in Figure 1. The first two, types *A* and *B*, are strictly for transformer stations while the other three combine the switching and transforming functions. Type *A* and *B* stations, automatically operated, are used for supplying moderate loads when 66-kv switching is not needed for the lines. The type *A* station usually has an additional partial back-up source or a modern 66-kv supply line properly protected against lightning and sleet and maintained with hot line tools. The type *B* station is used when two sources are required to provide a high degree of continuity. For both type *A* and *B* substations, transformer capacity is supplied in two 3-phase units, each capable of carrying the load responsibility of the station without exceeding its allowable overload.

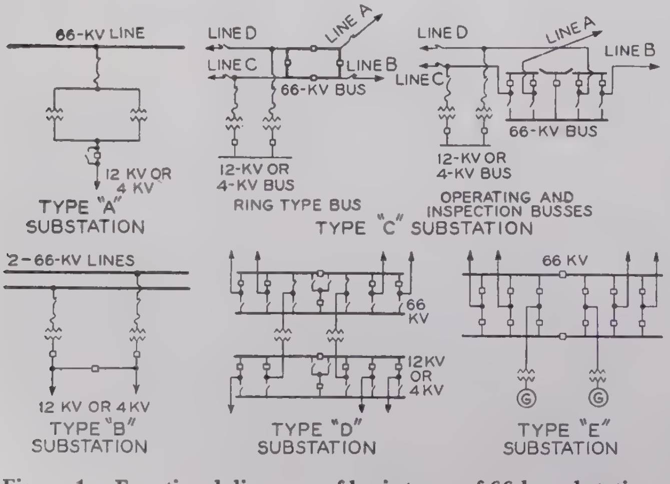

Figure 1. Functional diagrams of basic types of 66-kv substations

The type *C* substation is primarily a switching center for a limited number of 66-kv lines. The transformer capacity is installed as in a type *B* station by tapping two incoming lines directly. Thus the banks do not require a bus position and are independent of the continuity of operation of the bus.

Table I. Number of Company-Owned Substations

	As of Jan. 1, 1947	Planned Additions Through 1951
Type A	20	20
Type B	10	5
Type C	4	3
Type D	6	1
Type E	2	1
Nonstandard	12	0
	54	30

The type *D* substation is used where high concentrations of load require large transformer capacity and where switching must be provided for several lines. Both high- and low-voltage sides have operating and inspection busses. The operating busses are sectionalized automatically and protected by bus differential relaying. This type of station is particularly adapted to use where the low-voltage feeders are operated in a network because service can be maintained to half the feeders with trouble on any bus section.

The type *E* substation is used for very large concentrations of power, such as large generating stations or step-down centers from the 220 kv, where the two breakers per circuit are justified by the improved reliability and flexibility attained. Development of the system by the use of functional analysis and standard patterns tends to promote an orderly planning and design leading to minimum costs per unit of load and revenue.

The need and benefits of using a functional approach and standard patterns on this system are also evident from the numbers of the various types of existing and planned company-owned substations listed in Table I. In addition to the new stations listed, eight of the 12 nonstandard stations will be converted to standard types and eight other stations will be changed from one type to another in line with present-day requirements.

Digest of 49-273, "Functional Development of 66-Kv Switching and Transformer Stations," recommended by the AIEE Committee on Substations and approved by the AIEE Technical Program Committee for presentation at the AIEE Fall General Meeting, Cincinnati, Ohio, October 17–21, 1949. Not scheduled for publication in AIEE *Transactions*.

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Computer for Fractionation Calculations

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FELLOW AIEE

THE PETROLEUM and natural gas industries utilize fractionating columns to separate hydrocarbons of high volatility from hydrocarbons of low volatility. Each column, or tower, is a type of equipment which permits a liquid stream to cascade down over a series of trays or plates and allows a vapor stream to bubble up through the plates countercurrent to the liquid stream. The feed stream (containing several components such as methane, ethane, butane, propane, and so forth) enters one of the chambers part way up the column. Each of the components of the feed is present in varying amounts in the liquid stream falling from a given plate and the vapor stream rising from a given plate. The relative amounts of the several components in a given stream depend upon several factors including the temperature and pressure of the stream and the relative amounts of the liquid and vapor components in the streams approaching the plate. Within the column as a whole, large percentages of the less volatile components fall in liquid form toward the bottom, while large percentages of the more volatile components rise in vapor form toward the top. The liquid and vapor flows within the tower are maintained by supplying heat to the bottom of the column and removing it from the top.

The number of plates required by the column is a function of the required split between the hydrocarbon components, the amount of heat to be supplied to the column, the pressure at which the column is to operate, and the like. "Plate-to-plate calculations" are required to solve for the conditions upon a plate adjacent to a plate upon which the conditions are known, given boundary conditions of the system. When a sufficient amount of information is available, conditions in the column can be determined by advancing toward the center of the column plate at a time using the known conditions at the ends of the column.

The plate-to-plate calculations require the solution of a pair of simultaneous equations each of which contain two unknowns. Unfortunately, a number of the terms involved in the equations are nonlinear functions of one of the unknowns. The usual method of solving the plate-to-plate equations consists of assuming values for the two unknown quantities and substituting these values into the equations to determine whether the equations will balance. When a solution is obtained, the conditions upon one plate of the column are determined. The available information can then be substituted into the plate-to-plate equations, a subsequent solution of which will solve for the conditions upon an adjacent plate in the column, or tower.

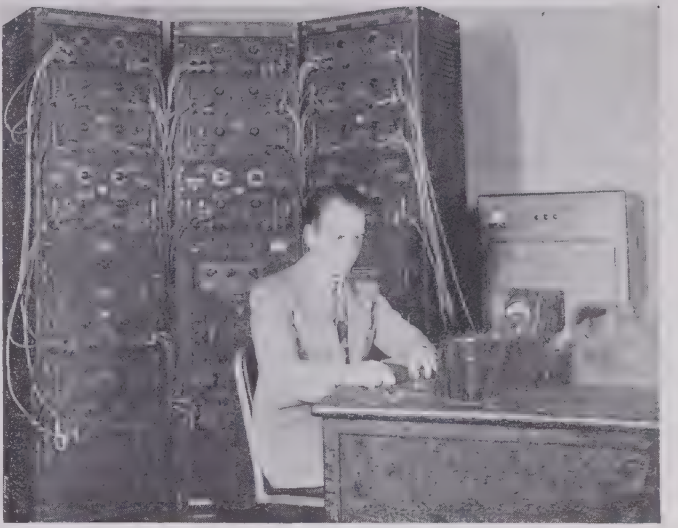

Figure 1. Console and associated amplifier racks of the analogue computer

An analogue type of computer that solves the plate-to-plate calculations in a fraction of the usual time has been designed and constructed at Northwestern University (refer to Figure 1). Each coefficient and variable in the plate-to-plate equations is represented either by the voltage gain of a voltage-divider network or by an amplifier within the computer. A 400-cycle signal voltage is supplied to the input of the computer circuit. The network elements have such a configuration that they successively operate upon the signal voltage in order to build up the various terms of the plate-to-plate equations. At appropriate points throughout the circuit, voltages are added as specified by the form of the equations. An indication of the balance of the equations is displayed by a pair of voltmeters (the meters located to the operator's right on the console of Figure 1). The computing machine solves the equations in a manner similar to the more usual methods.

Prior to the initial solution certain adjustments must be made upon the computing machine, so that it will be able to solve multicomponent fractionation problems involving a particular set of hydrocarbon components and will have solutions falling within a given range of temperature. Upon completion of these initial adjustments, every particular setting of each of two dials corresponds to the operator assuming values of the two unknowns and substituting these values in the equations. This arrangement allows the operator of the machine to make extremely fast trial selections of the two unknowns and immediately presents the operator with an indication of the balance of the two plate-to-plate equations. A solution of the plate-to-plate equations is obtained when the two voltmeters simultaneously indicate balance of the two equations.

Digest of paper **50-15,** "Analogue Computer for Multicomponent Fractionation Calculations," approved by the AIEE Committee on Computing Devices and recommended for presentation by the AIEE Technical Program Committee at the AIEE Winter General Meeting, New York, N. Y., January 30–February 3, 1950. Scheduled for publication in AIEE *Transactions*, volume 69, 1950.

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The authors are indebted to G. M. Brown of the Department of Chemical Engineering, Northwestern University, for the aid he presented in attacking the chemical engineering phase of the problem.

Electronic Motor Drives on Printing Presses

J. A. JOHNSON   E. M. STACEY
MEMBER AIEE

ROTARY WEB printing presses reached essentially their present form at least 50 years ago. Electric drives have kept abreast of press developments to produce a better product at higher speed. The resulting press drives are highly refined equipments designed to meet the special application problems of press operation.

Rotary presses draw continuous webs of newsprint from heavy newsprint feed rolls. Acceleration rates, to reach speeds of 1,500 feet per minute, must be limited to avoid breaking of the webs. A threading speed of $2^1/_2$ per cent of full speed is needed for leading the long webs through the press to the folder. Crisp, accurate inching action is necessary in order to position the plate cylinders for application of the type plates.

Smooth acceleration and deceleration over a five-to-one speed range must be provided. Initial adjustments are made at 20 per cent speed. Production is at 75 to 100 per cent speed. The electric drive must provide a large part of the braking torque for emergency stops.

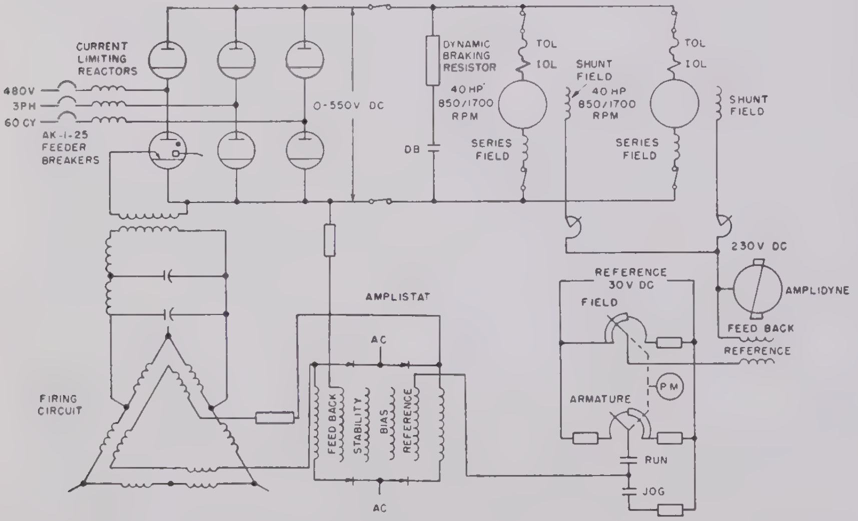

Figure 1. Schematic diagram of an electronic printing press drive

The 3-phase full-wave ignitron rectifier transforms the 440-volt 3-phase input power to direct current which is fed directly to the armatures of the press drive motors

The a-c double-motor drive has been used successfully as a press drive. It uses a wound-rotor main motor, with secondary resistance control, and a separate smaller motor for jogging and low-speed threading functions.

This drive, however, has certain inherent drawbacks. First, the extra threading motor, with overunning clutch and gearing, introduces undesirable mechanical complications. Secondly, efficiency is low at reduced speeds, wasting power and making necessary expensive provisions for getting rid of secondary resistor heat. Thirdly, speed regulation is poor at reduced speeds, making necessary special adjustments if correct operation is to be maintained as press loads are changed.

The electronic printing press drive eliminates these drawbacks. Jogging and threading, as well as high-speed operations, are accomplished by the main motors, eliminating the extra threading motor. Efficiency of the system stays at about 85 per cent over the full production range. Speed and acceleration rate are not materially affected by load change.

Power at 440 volts, three phase, is rectified to direct current in a 3-phase double-way ignitron rectifier and fed directly to the armatures of the press drive motors (Figure 1). Voltage is adjustable from zero to 550 volts by means of a closed-loop amplistat regulator acting to phase the tubes ahead or back as a function of a reference voltage. Speeds above motor base speed are obtained by motor shunt field weakening controlled from an amplidyne regulator. A motor-driven potentiometer gives 35-second timed acceleration from threading speed to full speed, with deceleration at the same rate. Any speed above $2^1/_2$ per cent can be held continuously and with essentially shunt speed regulation regardless of press size. Conventional dynamic braking can be set to give any desired rate of stopping.

First cost of a complete electronic drive is usually slightly higher than a-c wound-rotor drive, but certain savings tend to make up the difference. Annual savings resulting from higher efficiency at average production speeds often are a material figure. Electronic drive lends itself particularly well to production in factory-assembled and wired cubicles, giving the lowest possible installation cost. Moving parts have been reduced to a minimum, and power making and breaking contacts virtually eliminated by the use of ignitron tubes. Reduced maintenance can be expected from this simplification.

A number of electronic drives have been in regular production for over a year, and have proven satisfactory on the score of reliability and general performance. A total of 28 ignitron rectifiers, powering 5,000 horsepower of motors, are now installed in newspaper plants.

Digest of paper **50-34**, "Application of Electronic Motor Drives to Printing Presses," recommended by the AIEE Committee on Electronic Power Converters and approved by the AIEE Technical Program Committee for presentation at the AIEE Winter General Meeting, New York, N. Y., January 30–February 3, 1950. Scheduled for publication in AIEE *Transactions*, volume 69, 1950.

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Measurement of Tube Voltage Drop in Hot-Cathode Gas Tubes

E. K. SMITH

IN MANY industrial control applications, particularly in process industries, interruptions due to tube failures can be costly. Removal of gas tubes at fixed intervals to insure continuity of service does not improve reliability enough to be a solution. Statistically, a certain group of long-life tubes will be replaced by some short-life tubes. A means of anticipating end of life is, therefore, highly desirable.

Although there are other types of failure, the most common manifestation of end of life is an increase in tube voltage drop. On applications where this is the typical failure, measurement of tube voltage drop is a most useful tool for anticipating end of life.

Since several factors have varying effects on tube voltage drop, it is evident that measurements must be carefully considered before conclusions can be drawn regarding remaining life expectancy. Through a discussion of methods of measurement, interpretations of measurements, and presentation of some data, it is hoped that tube users will be encouraged to accumulate the tube voltage drop data that will enable them more accurately to predict end of life in their units.

In order to predict end-of-life of gas-filled tubes being used for industrial control, tests have been developed to show the voltage drop of these tubes while they are in use. As many tubes increase rapidly in tube voltage drop in the latter part of their useful life, these tests indicate the time when the tubes should be replaced to prevent emergency shutdowns.

There are several different methods of measuring tube voltage drop. Brief descriptions are given in the following paragraphs.

For the relatively few cases where tubes are used on direct current the drop can be read directly with a voltmeter at the desired value of current. Since tube voltage drop varies a few volts with current, this method is not precise enough to yield the information necessary to predict end of life if the tubes are to be used on alternating current.

An accepted method of getting more pertinent information while the tube is operating on alternating current is with a wattmeter and d-c ammeter. Typical connections are shown in Figure 1. The tube watts, obtained by connecting the current coil in series with the tube and the voltage coil across the tube, divided by the average current in amperes gives the average tube voltage drop. With the usual wattmeter of sufficient sensitivity operation must be at low voltage. Care should be taken to correct the wattmeter reading for coil losses, if sizable, by connecting the voltage coil to read the watts lost in the current coil under load. If the load is resistive the drop is the average over the range of current from zero to the peak which is roughly π times the average current.

Methods giving instantaneous values of drop are often preferable. This is due to the fact that the instantaneous tube voltage varies more with current than the average arc drop because of increased emission from ion bombardment and cathode heating by load current.

The vacuum-tube voltmeter may be used to measure the highest point in the tube voltage drop curve. Some provision must be made in the grid circuit of the voltmeter vacuum tube so that no voltage will be recorded before current passes through the tube under test. Otherwise, the starting voltage of the tube will be measured. There are two limitations to readings obtained by this method. First, a tube whose cathode develops hot spots or sputters during the test may read moderately low in tube voltage drop. Second, the reading will be misleadingly high if there are any plasma oscillations. These oscillations will be mentioned later in discussing the voltage-current curve.

Since the peak drop does not tell the complete story, particularly if it does not coincide with maximum current, a cathode-ray oscilloscope seems to be the most satisfactory tool. The simplest method of using the oscilloscope, and one which can usually be employed without removing the tube from service, is to connect one set of deflection plates across the tube with a time sweep on the other set. With sufficient sensitivity to give good tube voltage drop readings, most of the remainder of each cycle will be off scale. To obtain the required sensitivity with direct connection to the plates it is usually necessary to reduce the accelerating voltage on the cathode-ray tube. The recent oscilloscopes with good d-c amplifiers allow use of the normal input terminals. The small portable instruments with d-c amplifiers now available are particularly useful for testing the tube without removing it from service.

A voltage-current curve may be obtained with an

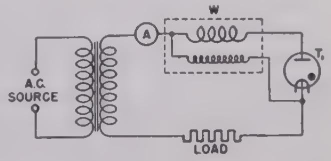

Figure 1. Using this test circuit, the tube voltage drop on alternating current may be computed by dividing the tube watts by the average current

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Full text of a conference paper, "Arc Drop of Hot-Cathode Tubes in Service—Measurement Methods and Data," presented at the AIEE Winter General Meeting, New York, N. Y., January 30–February 3, 1950.

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oscilloscope on a tube under normal operating conditions. A typical connection for a tube in a single-phase full-wave circuit is shown in Figure 2. The deflection plates across the tube measure tube voltage drop and the plates across the resistance give a current indication. It will be observed that the circuit must contain some noninductive resistance.

Ionic bombardment and the heat produced by it at the cathode both influence tube voltage drop. It is, therefore, helpful to obtain a voltage-current curve with as little heating effect as possible. This is accomplished by passing single half-cycle or quarter-cycle pulses.

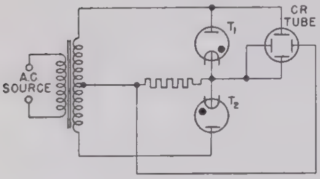

Figure 2. Test circuit for obtaining the voltage-current curve with an oscilloscope so that the tube need not be removed from service

A common laboratory method is shown in Figure 3. The tube to be tested is connected in series with a known value of resistance across an a-c source. Voltage and resistance are chosen to give the desired maximum current, usually the peak instantaneous current rating of the tube, at the peak of the voltage cycle. Sensitivity may be adjusted to keep the complete sweep on the scope.

If the tube under test is a grid-controlled tube, the grid circuit may be arranged to give the single half- or quarter-cycle pulse. The grid circuit may be pulsed manually. For greater flexibility, so that heating effect may be shown, fixed or variable resistance-capacitance elements may be included to give pulses at predetermined intervals. For the same test on a rectifier tube, it may be put in series with a grid-controlled tube.

Another laboratory method is the discharging of a capacitor through the tube to give the pulses. A voltage-current trace can be obtained as before. This method allows high current pulses of exceedingly short duration while keeping the average current at a minimum.

Wherever readings by any method are to be used for comparative results on directly heated cathodes, two aspects of filament voltage should be considered. First, since emission, and therefore tube voltage drop to quite an extent, depend on cathode temperature, the filament voltage should be held constant. Second, the instantaneous value of filament voltage is changing throughout each cycle. If filament voltage is in phase with anode voltage, the peaks will occur simultaneously, and half the filament peak (that is, 1.75 volts on a 2.5-volt filament) may be added to or subtracted from the true peak tube-voltage drop, depending on the connection of load return lead and oscilloscope lead to the filament. This inaccuracy can be minimized by bringing both load return and oscilloscope cathode connection to the center tap of the filament transformer and using a consistent filament voltage to anode voltage phasing for testing. Consideration of what the tube voltage drop, as read by different methods, shows regarding tube conditions may help determine which test method may be used to best advantage.

Figure 4*A* is a sketch of a typical trace observed with a single half-cycle pulse. *S* is the anode voltage at which the tube fires and current starts to flow. At *L* sufficient ions have been formed and distributed to produce arc conditions. Usually at a slightly higher current a minimum arc voltage *M* will be observed. The region between *L* and *M* may be a solid line as shown, or may be a region of high-frequency oscillations. These oscillations may usually be traced to changes in the distribution of ionization throughout the plasma. According to life test data, they do not affect tube life either advantageously or adversely. With a tube operating at moderate current and using the vacuum-tube voltmeter for measuring, these peaks may be recorded and give results which are subject to misinterpretation.

Figure 4*B* shows two more traces which are sometimes observed on a half-cycle pulse. Curve *A* shows that the voltage at the higher currents is less on the back side of the half cycle. Ion bombardment or cathode heating effect has enhanced the emission during the first portion of current conduction.

Curve *B* of Figure 4*B* shows a typical trace for a cathode which has developed a hot spot. This indicates that some portion of the cathode has suddenly become highly emissive and has retained this increased emission for the balance of the cycle. That brings up an important point in connection with cathodes for gas tubes. They must be capable of withstanding bombardment of ions with energies corresponding to the arc voltage. Such bombardment may increase the emission at a hot spot, as shown, but coincident with the hot spot there may be a loss of cathode material. This would be called sputtering and the point at which it occurs, a sputter point. It seems advisable to look upon all such breaks with suspicion and call them sputter points.

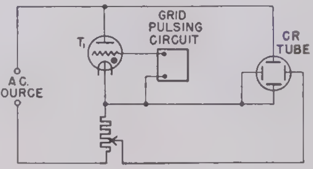

Figure 3. Test circuit used in pulse test to obtain voltage-current curve with minimum effect of ionic bombardment or heating

Sputter, for cathodes of given surface composition and processing, usually does not occur at a particular current or voltage. It seems to co-ordinate better, in general, with the product of the two. There is, however, a wide variation in the value of voltage-current product at which sputter appears between various types of oxide cathodes. Some very emissive coatings will sputter at low voltages. Others, less emissive but tougher, will not sputter up to voltages three or four times as much. Provided the sputter point is at a heavy current, coatings with high product points are preferable for long life in gas tubes, even if the voltage is moderately high.

It has been suggested that even though no sputter point is observed, if the tube voltage drop has exceeded some disintegration voltage the oxide cathode will still lose emission rapidly due to loss of material. Such a disintegration voltage has been stated by Hull[1] to be around

25 volts for thoriated-tungsten cathodes in different gases. That loss of a specific amount of material varies with coatings has been shown by Koller[2] who obtained threshold values ranging from 14 volts for barium on tungsten to 45 volts for cold oxide coatings. The tungsten-type cathodes are known to be unsatisfactory for use in gas tubes. The oxide cathodes of Koller were prior to the amphoteric-nickelate type of oxide cathode widely used in present gas tubes which can stand high-voltage bombardment for long periods.

Further, there is evidence that just as different types of coating have varying sputter characteristics, so their emissions under bombardment vary. This is sometimes observed on short time tests. Instead of a single half-cycle pulse, repeated pulses can be given, but at a relatively slow rate so that the cathode temperature is not raised appreciably. With some cathodes the traces for succeeding pulses will coincide well, while on others it may either slowly or rapidly increase or decrease. An increase may be evidence of a disintegration voltage for that particular coating. This slow pulse test just described may be the ideal test for tubes to be used in applications such as welders, ignitor firing, and others.

Ionic bombardment and tube current flowing through the cathode both have a cathode heating effect. It may be important to know the tube voltage drop at the higher temperatures thus obtained under load conditions. This may be accomplished by decreasing the intervals between pulses until the average current equals any desired value up to the average current rating of the tube. Here, again, different tubes will react differently as the average current is increased.

As the test condition approaches operation every cycle, the wattmeter method can be substituted for the oscilloscope method without too much loss of information. While the peak value will not be observed, the reading will co-ordinate well with the peak value. It does have the advantage of giving watts lost in the arc directly, which cannot be obtained by the oscilloscope.

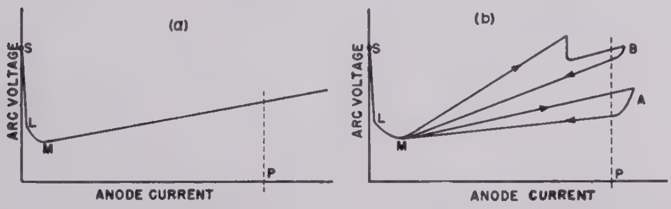

Figure 4. Typical arc voltage-anode current characteristics of gas tubes with half-cycle current pulses

A—No effect due to ion bombardment

B—Curve A shows that voltage at higher currents is less on the back side of the half cycle. Curve B shows the oscilloscope trace of the voltage of a tube which has developed a hot spot on the cathode

Life of a given tube depends in a complex way upon the operating duty of each of its many ratings and upon the abnormal operating conditions throughout life. So far tube life has not correlated with any initial test measurements by any of the foregoing tests provided the initial test reading is better than some minimum value. The complexity of all the different operating duties and conditions has made it impractical for tube manufacturers to life test under enough of the possible combinations to give generally applicable rules for predicting end of life. As a rough guide a value of average or peak tube voltage drop is sometimes given. However, on a given installation where high tube voltage drop is the typical failure, a useful tube voltage drop limit may be determined by one of the foregoing tests in service and used thereafter successfully for the particular unit as long as its operating conditions remain reasonably uniform.

The following data give some typical values on tube voltage drop throughout life under a few typical operating conditions, as measured by some of the previously described methods. Figure 5 shows plots of readings taken on both anodes of a full-wave rectifier having a cathode for each anode. The data are typical of many such curves. It will be noted that at 50 hours both cathodes gave equal tube voltage drops. Also, both tube voltage drops became lower during the first 600 hours. The minimum drop extending over most of the operating life is typical, as is the upswing toward the end of life. Unfortunately the upswing and recovery shown by the dotted curve, though not typical, is not rare. If the initial upswing had continued for two more volts the manufacturer's value for end of life would have been reached, the tube removed, and 25 per cent of the potential life sacrificed.

The tube voltage drop values of curves of Figure 5 are oscilloscope readings of the peak with the tube in the life-test circuit. The isolated points at start and end of life were taken with the tube in a half-cycle pulse tester at rated peak current. These points and the curves show the extent of correlation between the two peak tests for this tube in this particular duty.

Figure 6 gives additional typical curves using the wattmeter method. Readings were taken by operating at rated average current through a resistance load for one minute before reading. Except for curve *2*, therefore, the readings were not taken near life test conditions. Both curves *2* and *3*, however, show the minimum mentioned previously. They have not reached end of life.

Curve *A* of Figure 6 is a plot of gas pressure, expressed in arbitrary units, of the tube from which curve *2* was obtained. Curve *A* shows no appreciable change in gas pressure has occurred in 11,500 hours. This is quite typical of properly-designed tubes run within their ratings.

Data given so far might indicate that either average or

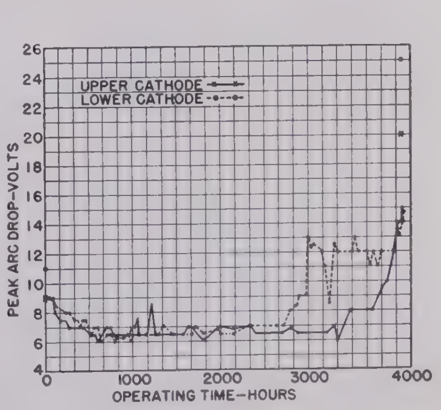

Figure 5. Arc voltage versus operation time on both anodes of full-wave rectifier operating at 140 per cent of average current rating and 110 per cent of peak current rating

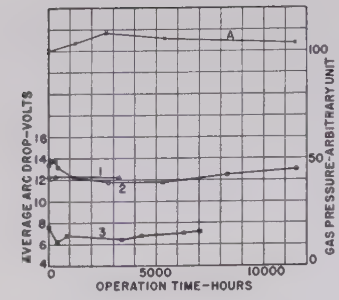

Figure 6. Arc voltage (1, 2, 3) and gas pressure (A) versus operation time

1. Tube run at hot cathode, no load
2. Tube run at 100 per cent rated average current, 20 per cent rated peak current
3. Tube run with current 240 per cent of rated average for three seconds, off for ten seconds

peak tube voltage drop may be used to show if there is an upswing indicating approaching end of life. This is not always true. Two tubes were operated at 125 per cent of peak current rating with complete half-cycle pulses into a resistance load every tenth cycle. This gave an average current of approximately 50 per cent of rating. The arc drop of both tubes, measured at peak current, had increased during the time they were operated. Average tube voltage drop measurements show no increase for one tube and an insignificant amount for the other. The data are shown on Table I. Obviously the peak current test is the correct one for this application. However, the average tube voltage drop test indicates both tubes should still give long life in a lower peak current circuit. The tubes were not continued beyond the hours shown, but tube *1* seems to be failing at a slower rate. This was predicted at the start by observations taken after 360 pulses.

Table I. Peak Tube Voltage Drop versus Number of Pulses for Two Grid-Control Tubes

	Voltage Drop at 125 Per Cent Rated Peak Current. Half-Cycle Oscilloscope Method		Average Voltage Drop at 100 Per Cent Average Current. Wattmeter Method	
Pulses	**Tube 1**	**Tube 2**	**Tube 1**	**Tube 2**
0	35	20	10	10
360	32	30		
1.04×10^7		40		11
1.25×10^7	45		10	

It has been pointed out that different limits and interpretations may apply to tubes with different cathode materials. Due to the countless possible combinations of average and peak currents, different applications may call for different tests and end of life limits. At the same time, it is felt that the data available, of which that presented here is typical for one type of cathode, indicate a strong possibility that many tubes increase in tube voltage drop rather rapidly in the latter part of their useful life. This should encourage the user of fair quantities of tubes of the same type and manufacture to set up periodic check tests. A reasonable amount of data may well establish the limits at which such tubes should be removed to prevent emergency shutdowns.

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Relaying and High-Speed Reclosing on Long, Heavily-Loaded Lines

C. E. PARKS W. R. BROWNLEE

PRESENT-DAY large, interconnected transmission systems, such as the hypothetical one under consideration in this study, illustrated in Figure 1, have many common problems with regard to economical line loading, optimum placement of generating capacity, and satisfactory solutions of protective relaying and reclosing requirements to provide the best over-all system performance.

Economies in generating costs have dictated the location of generating plants. These chosen locations are, in many cases, remote from the points of large load concentrations. This fact has led to close study of the economics of transmission; invariably included in these studies is the subject of adequate relaying facilities to be applied which will best satisfy the increasingly stringent line loading requirements. It is well recognized that there is a continuing trend toward higher normal and emergency loading of transmission lines in order to take full advantage of their capability.[1] Higher standards of service at reasonable investment costs necessitate the consideration of a minimum number of transmission paths between load and generating areas. This dictates operation of lines under short-time emergency loadings up to twice normal. These lines also must operate satisfactorily for very short intervals following system faults at even higher load or swing currents until normal system operation is restored.

Full consideration must be given to equipment and methods to develop the full emergency (swing) capability of the transmission system. In the past, system separations

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Full text of paper **50-16,** "Consideration of Requirements and Limitations of Relaying and High-Speed Reclosing on Long and Heavily-Loaded Transmission Lines," recommended by the AIEE Relay Committee and approved by the AIEE Technical Program Committee for presentation at the AIEE Winter General Meeting, New York, N. Y., January 30–February 3, 1950. Scheduled for publication in AIEE *Transactions,* volume 69, 1950.

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have been attributed to "out-of-step" or "simultaneous-fault" conditions when actually such conditions may not have been present or else could have been prevented easily by proper study and application of adequate protective relay systems. Use of the automatic oscillograph has done much to disprove complicated theories with regard to unexplainable system operations making it evident that further study of the problem would have produced solutions which would have eliminated such situations which had previously been considered as impossible to prevent.

Third in a series of articles* covering the protection of transmission lines, this presents the requirements and limitations of relaying and high-speed reclosing on long and heavily-loaded transmission lines. The system provides protection that will withstand heavy emergency loads and swing current without unnecessary tripouts.

The hypothetical system illustrated in Figure 1 is representative of systems with which all transmission engineers are familiar. The purpose of this article is to outline the relaying requirements of the two 70-mile 138-kv lines connecting station *A*, a base-load generating plant, with a net-load interconnected area, substations *H* and *J*.

The two 70-mile transmission lines under discussion are required to serve primarily as the major power supply to the load areas at stations *H* and *J*. The generating capability of the local station *D* is assumed to be limited by lack of available cooling water, and the generating cost differential between stations *A* and *D* justifies substantial transmission of power to the load area near station *D* from station *A* in spite of rather heavy transmission line losses. Maintenance outages at station *D* may require heavier transmission line loading for periods totaling perhaps three months of the year than would be economical for year-round operation. A typical resultant heavy loading condition may be taken as 90 to 95 megawatts for each of the two 70-mile lines. While lines of this length are not ordinarily considered as long lines the heavy concentration of generating capacity at each terminal and the high normal line loading result in characteristics of long-line variety.

Relaying requirements for phase-to-ground faults on the two lines are not too severe. The 138-kv transformer bank neutrals are solidly grounded at each terminal station of the lines, thus providing adequate zero-sequence currents under practically any system operating condition. The mutual coupling between the lines must receive close scrutiny, however, to ascertain that positive and selective operation occurs for ground faults at any point on the lines near stations *H* and *J*, particular attention being paid to the back-up ground relays on the line between stations *H* and *J*.

Phase relaying requirements are more complex, and the solution to proper application must receive careful consideration, realizing that some compromises must be tolerated to meet the conflicting system operating requirements. The conditions to be met are summarized as follows:

1. Positive and complete fault protection for all generating and system operating conditions.
2. Adequate allowance for conditions presented by fault arc impedance.
3. Some measure of backup protection should the proper circuit breaker fail to operate on fault.
4. Operating reliability with approximately double normal load plus the addition of current caused by system oscillations.
5. Characteristics suitable for high-speed simultaneous tripping and reclosing.

It is of further importance to recognize that certain combinations of circumstances may cause actual out-of-step conditions to exist between systems, across one or both of the 70-mile lines. In this case, it is imperative that the two systems be separated on the first complete swing in order to prevent serious disruption of the complete power system at many points. This consideration obviates the use of any time-delay impedance sequence interlocking arrangement applied to prevent out-of-step tripping on swing currents.

In order to provide information on phase relaying for the hypothetical system under consideration, a-c calculating board studies have been made, based on 3-phase faults with 1-cycle relaying and 5-cycle circuit-breaker tripping. For simplicity 3-phase faults only were studied. These are only slightly more severe to the over-all system than those involving two phases and ground, which are reasonably common.

Figure 2 shows the impedance presented to the phase relays at station *A* on the line to station *H* for a fault at station *A* on the line to station *J*; this fault was cleared at both ends in six cycles, reclosed in 20 cycles, and retripped in six cycles. Swing curves taken for the system under this condition indicate that system itself is stable. For comparison, the characteristics of impedance, reactance, and modified impedance distance relays are illustrated with conventional settings of Zone 1 and Zone 2 tripping (Zone 3 not shown). The reactance units require a voltage re-

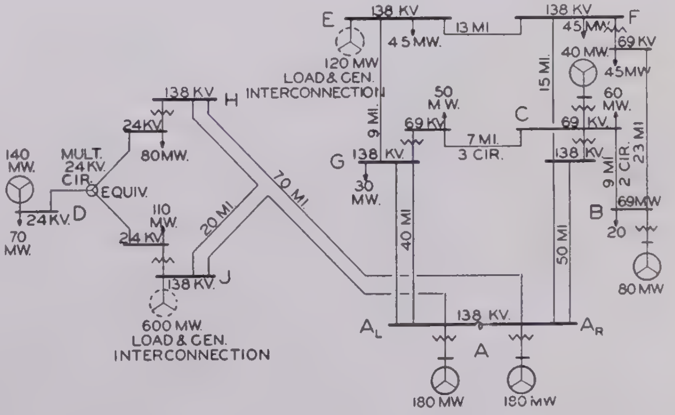

Figure 1. Representative transmission system

The lines considered in this article are the two 70-mile 138-kv lines connecting generating station A with substations H and J

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* See "Protection of Short Transmission Lines" by W. E. Marter (*EE, Mar '50, pp 196–9*) and "Relay Protection for Transmission Lines" by J. H. Kinghorn (*EE, Apr '50, pp 314–19*).

The authors wish to acknowledge the assistance of E. L. Harder and A. J. McConnell who made the a-c network analyzer and d-c calculating board studies on the system analyzed in this article.

straint directional starting unit, and the plain impedance elements require a directional unit.

Figure 3 shows the impedance presented to the phase relays at station *A* with a fault on the double circuit line at station *A*. This diagram indicates that successful reclosure of both lines will prevent system instability; however, if only one line recloses successfully and the other recloses on a fault, the system will become unstable and separate on the line which reclosed successfully. Successful reclosing of the lines following a transient fault requires that the phase relays should not trip on the resulting swing currents. For comparison, Zone 1 and Zone 2 settings of another form of modified impedance relay (with directional unit) are shown, indicating that the swing current is within the Zone 2 setting for at least one-half second.

Figure 4 applies to another system and illustrates the nature of swings presented to the phase relays on a single-line transmission system joining two areas when a fault occurs on an external line of one of them, the fault being cleared rapidly at the near end and by Zone 2 timing at the far end. For comparison, a smooth line is plotted based on treating the areas as a 2-machine problem. Variations about this simplified line are due to swings of individual generating stations of the area in which the fault occurred.

This effect is significant because the relays on such a tie line must remain inoperative for impedances corresponding to as much as 30 apparent electrical degrees greater than the 2-machine stability limit, whereas the transient stability limitations of a tie line are properly evaluated on an approximate 2-machine basis.

Two possible solutions may be considered for the 70-mile-line problem under consideration. One of these might be a carrier pilot scheme using a modified impedance or "mho" element, shown in Figure 5. In this scheme, a long-time back-up distance element (omitted for simplification) is in operation at all times, but Zone 1 distance relay tripping (not shown) is normally cut out of service by the carrier control switch. The displaced circles operate to stop carrier, set up the tripping circuit, and also to control Zone 2 timing, and the larger impedance circles start carrier. However, the presence of a carrier signal cuts out Zone 2 tripping. Thus, for normal operation, all line faults are cleared by carrier relays, but it is necessary for the swing current impedance to enter the zone of both circles (near and far terminals) to cause tripping where the backup element is set for a time long enough to avoid tripping on swings.

When carrier-pilot protection is to be added to a line already equipped with distance relays, the use of the "phase-comparison" type of carrier relaying may have advantages since this type of carrier protection is immune to swing currents. Under this scheme, it would become necessary to provide for tripping on actual out-of-step conditions using a modified setting of the distance relay elements. The reach of the Zone 1 elements of the distance relays may be shortened so they just overlap, thus insuring that at least one end of the line will trip on actual out-of-step conditions but minimizing the likelihood of undesired tripping. It would become necessary to make Zone 2 tripping nonautomatic for normal operation and to set Zone 3 timing long enough to prevent tripping on system swings.

Application of the phase-comparison type of relaying would have to be studied very closely to determine the sequence quantities which would be employed for fault detection. Due to the heavy load currents, both normal and abnormal, which flow on the two lines which are involved, the relay which is applied must be able to discriminate correctly between normal and fault conditions. If such a relay is completely desensitized for load currents, faults beginning as 3-phase line faults would not be cleared correctly.

Each of the foregoing schemes have serious limitations and represent severe compromises, especially in backup protection.

It has been assumed throughout this discussion that high-speed reclosing would be applied on the two tie lines under consideration. This, of course, requires that carrier-pilot relaying of some form would be installed to obtain

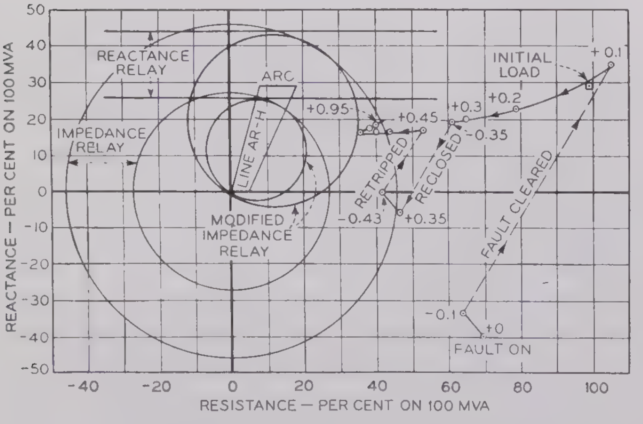

Figure 2. Impedance presented to the phase relays at station *A* on the line to station *H* for a fault at station *A* on the line to station *J*

This fault was cleared at both ends in six cycles, reclosed in 20 cycles, and retripped in six cycles

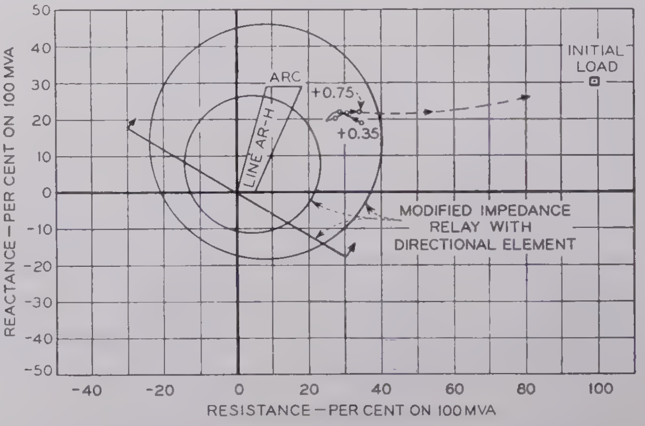

Figure 3. Impedance presented to the phase relays at station *A* with a fault on the double circuit line at station *A*

Successful reclosure of both lines prevents system instability, but instability occurs if only one line recloses successfully

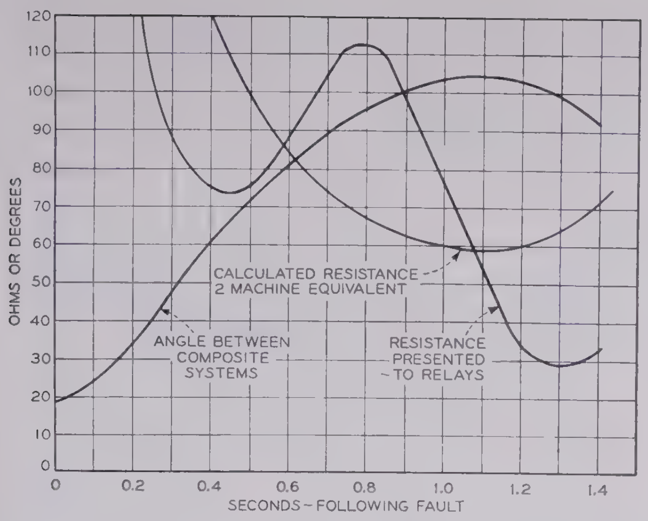

Figure 4. Variation of impedance at relays with external fault cleared sequentially

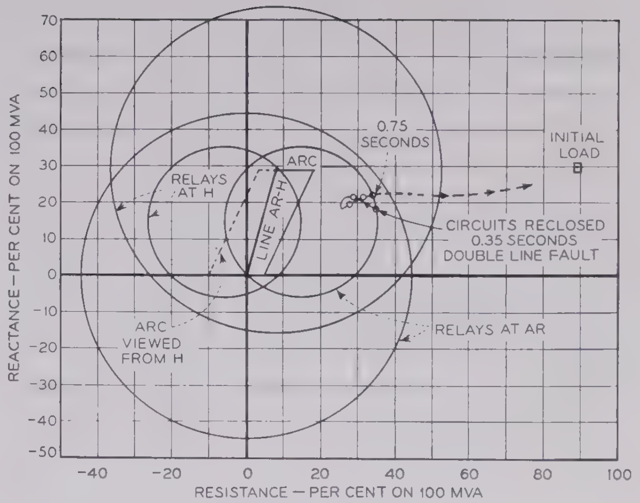

Figure 5. Carrier pilot protection for long lines

For normal operation all line faults are cleared by carrier relays, but the swing current impedance must enter the zone of both circles to cause tripping where the backup element is set for a period long enough to avoid tripping swings

simultaneous fault clearing at each terminal of the lines. Generating conditions on the two portions of the system being studied further require that the resynchronizing of the two systems must be accomplished very rapidly if serious load-generation unbalance diffculties are to be avoided in the vicinity of stations *D* and *J*.

The most simple and inexpensive form of high-speed reclosing would be of the 3-pole type.[2] However, the serious stability problems that present themselves under any type of fault on one or both lines, whether complete successful 3-pole reclosure is accomplished or not, leads to the conclusion that serious study should be given the application of selective or single-pole tripping and reclosing.[3,4] In case of transient faults involving only one phase and ground, the faulted phase only would be tripped at time of trouble and reclosed at high speed. This would usually result in the maintaining of some tie between the two systems, even with certain phases of both circuits being open at time of fault.

The phases which remain as ties between the two systems would carry synchronizing and some load current, thus retarding the angular drift between the systems during the dead time when the faulted phases are being restored to service by high-speed reclosing action. Determination of the type of reclosing which is to be employed will depend on further stability analyses, and on the relative number of single-phase-to-ground and multiphase faults expected, both for single-line and double-circuit faults.

CONCLUSIONS

Certain salient points which may govern or determine the selection of relaying and reclosing applied to a hypothetical system have been discussed. It is realized that each power system will require individual study for the selection of the appropriate protective scheme. However, it is believed that a large number of power systems will contain transmission links of the type to which the following conclusions may well apply.

1. Modern transmission-line loading practices are such that they require relaying systems which have greatly improved discrimination so that they can

(*a*). Withstand heavy emergency loads and swing current without unnecessary tripouts.

(*b*). Provide positive fault protection with allowance for arc impedance.

(*c*). Withstand swings inherent with high-speed reclosing.

(*d*). Provide at least some measure of backup protection.

2. High-speed reclosing of important tie lines should receive favorable consideration. Either 3-pole or single-pole reclosing may be applied, depending on the system stability characteristics and on the number of single-phase-to-ground and multiphase faults. Either type of reclosing imposes severe requirements on transmission line relaying.

3. Distance relay elements with modified impedance characteristics provide reduced susceptibility to swing current but are usually not sufficient for the more severe applications.

4. Time-impedance sequence blocking is seldom applicable to the longer tie lines, since system reliability requires that an actual out-of-step condition be cleared on the first swing.

5. Carrier relaying based on modified impedance relay elements can minimize undesired tripping, provided the first and second zone distance relay back-up elements are normally out of service.

6. Relaying schemes which minimize the possibility of incorrect tripping involve severe compromise with backup protection, especially protection against the rare failure of a circuit breaker to trip.

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Thermal Resistance Between Cable and Duct

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ONE STEP in the calculation of underground cable temperatures involves the determination of the temperature rise of the cable surface above the immediately surrounding enclosure such as a duct structure or a gas- or oil-filled pipe. Since the intervening medium is a fluid, the mode of heat transfer simultaneously involves convection, conduction, and radiation.

The semiempirical methods now in use for this determination in the case of cables in duct are not entirely satisfactory, and with the advent of gas- or oil-filled pipe-type cables there has arisen a definite need for a method of evaluation for these cable types as well.

Because of the complex nature of the problem and the number of independent variables which are present, it is impractical to cover completely all possible combinations which may be met in practice solely by tests. By developing the theoretical relationship between the variables, however, it is possible to develop procedures by which the test data available may be analyzed in such a way that relatively simple working expressions may be derived which may be applied with sufficient practical accuracy over the entire working range.

The theoretical relationships in the case of cables in duct or gas-filled pipe may be simplified to the following general form:

$$H_{sd}D_s' = \frac{1}{a\Delta T^{1/4}P^{1/2}/D_s'^{1/4}+b} \text{ thermal ohm feet inches} \tag{1}$$

in which H_{sd} is the thermal resistance, and ΔT the temperature drop between cable and duct or pipe, D_s' is the effective diameter of the cable or group of cables, P is the pressure in atmospheres, and a and b are constants. For oil-filled pipe the corresponding relationships are

$$H_{sd} = \frac{1}{a'D_s'^{3/4}\Delta T^{1/4}T_m^{3/4}+b'} \text{ thermal ohm feet} \tag{2}$$

in which T_m is the average temperature of the oil.

From an analysis of the test data obtained the constants a, b, a', and b' have been determined, thus permitting the evaluation of H_{sd} over the entire operating range.

In the case of cables in duct, it is customary to express the thermal resistance between cable and duct wall in terms of an effective surface resistivity factor β according to the expression

$$H_{sd} = 0.00411\,\frac{\beta}{D_s'} \text{ thermal ohm feet} \tag{3}$$

where β is expressed in degrees centigrade square centimeters per watt. Furthermore, it is preferable to utilize Q, the heat flow in watts per foot, rather than ΔT in the variable parameter, since the latter is equal to QH_{sd}. By means of these relationships the values of β as a function of $(Q^{1/2}P/D_s')^{1/2}$ thus determined are shown in Figure 1 for cables in single dry ducts and in gas-filled pipe. In utilizing the value of β for single dry fiber duct H_{sd}, as determined from equation 3, should be increased by 0.33 thermal ohms to account for the greater thermal resistance of the fiber duct than the section of concrete duct structure which it replaces. Figure 2 presents H_{sd} for oil-filled pipe as a function of $(QD_s'^3T_m^3)^{1/4}$.

As indicated on Figures 1 and 2 for representative conditions, the effective surface resistivity factor β used in equation 3 is equal to 800 degrees centigrade square centimeters per watt for cables in pipe and in single dry terra cotta or Transite ducts at atmospheric pressure and is somewhat higher for cables in single dry fiber duct. For cables in gas-filled pipe-type installations at 200 pounds per square inch β is 450, and it is 350 for cables in oil-filled pipe-type installations.

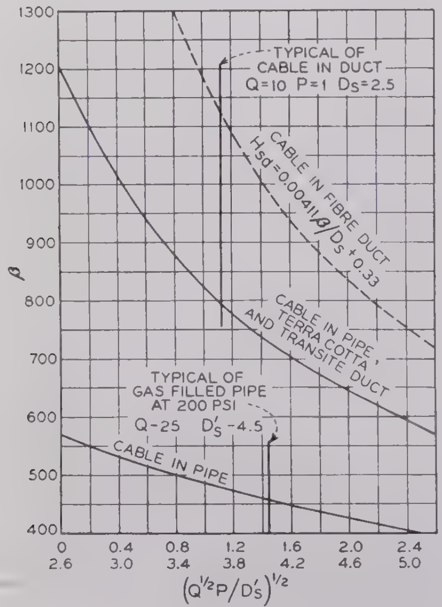

Figure 1. Values of β for cables in single dry ducts and in gas-filled pipes

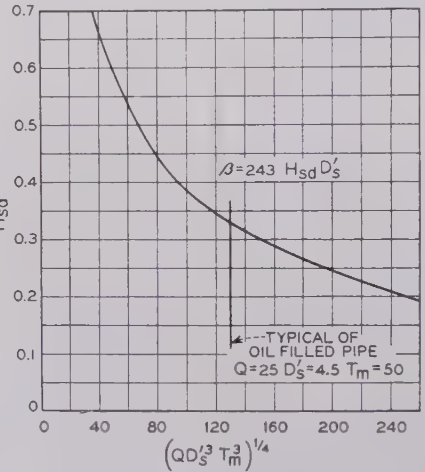

Figure 2. Values of thermal resistance H_{sd} in thermal ohm feet to be used in calculating the temperature rise of underground cables in oil-filled pipe as a function of $(QD_s'^3T_m^3)^{1/4}$; for representative conditions the effective surface resistivity factor β is 350 degrees centigrade square centimeters per watt

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Digest of paper 50-52, "The Thermal Resistance Between Cables and a Surrounding Pipe or Duct Wall," recommended by the AIEE Committee on Insulated Conductors and approved by the AIEE Technical Program Committee for presentation at the AIEE Winter General Meeting, New York, N. Y., January 30–February 3, 1950. Scheduled for publication in AIEE *Transactions*.

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The Metrotype System of Digital Recording and Telemetering

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Electrical quantities are automatically measured and recorded in numerals at predetermined intervals by the Metrotype system. Readings may be telemetered over a single channel for any distance. This article describes the process by which the instrument measures, telemeters, and prints the readings on a "log sheet."

THE YEARS since the war have been highlighted by ever-increasing costs of production. With such a condition existing, the need for automatic devices to monitor and control processes becomes increasingly urgent. The need for devices which would provide data is felt even more pressingly. If additional labor to read curves, instruments, and so forth, can be eliminated and the data obtained in numerical form, even further advantages can be obtained.

The Metrotype is a system of making measurements and recording them in digital form. If telemetering is required, each reading is transmitted singly and recorded in tabulated form. Only one transmission channel is required and this can be of telegraph quality. The name Metrotype is derived from the Greek words metron, to measure, and typo, to mark.

There are several ways in which an electrical quantity may be measured. The usual ways are an indicating instrument or a curve-drawing instrument. The method of making a measurement by the direct writing of the numbers has not been generally used other than in digital counting machines (the cash register or adding machine). Before the war, several machines which make printed electrical measurements were built and used,[1] but they were subject to many difficulties. A machine such as the Metrotype which can make sequential readings and transmit these readings to a distant point is an improvement on the prewar machines.

The machine to be described will select in sequence the quantities to be measured, make the measurement, transmit these readings as far as desired, and record them in numerical form properly tabulated. A complete 3-digit reading can be measured and recorded in 0.8 second. It combines the electronic computer technique with that of the printing telegraph. The result is a measuring instrument which makes readings automatically in numerical form. Standard paper with as many copies as desired may be used to record the results.

SYSTEM ARRANGEMENT

The block diagram of Figure 1 indicates the interrelationship of the various components. The master control is inherent in the teletype (*TTY*) transmitter. This unit controls a line relay which in turn will operate a standard teletype printer. The unit can be started by a clock, manual switches, or any other starting circuit, and will generate the teletype codes[2] as required by the master switch and the number-mixing relays.

In order to sequence the operations properly, a master switch is provided. Stepping of the master switch is controlled by the *TTY* transmitter. The master switch establishes the proper framing functions for the printer. It determines when the circuit selector will operate. It provides a method for homing the circuit selector to the proper starting point, and it controls the operation of the print sequence control. At the end of the printing cycle it turns off the printer and equipment.

The print sequence control is initiated by the master switch after the printer has been properly framed. As it runs, it selects the circuit to be measured, clears the electronic counters, pulses the step voltmeter, operates the digital sequence of the number mixer, and inserts the space function following the numbers.

The quantity to be read enters through the circuit selector and appears as a voltage at the step voltmeter. The latter generates a number of pulses proportional to the voltage being measured. The pulses are counted by the electronic counters and held in the form of an electrical condition in the various stages of the counter.

The number mixer consists of relays and tubes which receive control information from the electrical conditions of the electronic counters and the print sequence control and translates this information into teletype code. The teletype

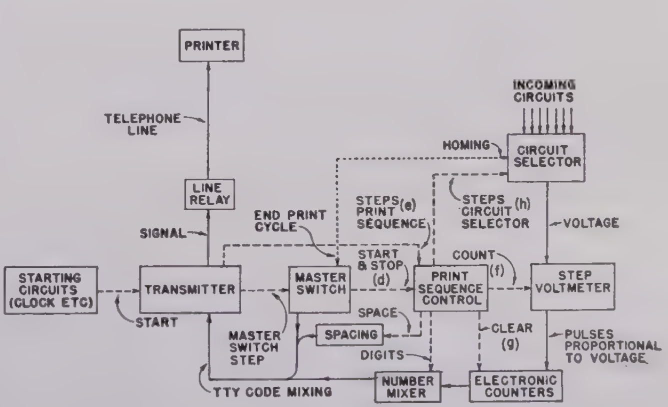

Figure 1. Block diagram showing components of Metrotype system

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Full text of paper 50-84, "The Metrotype System of Digital Recording and Telemetering," recommended by the AIEE Committee on Instruments and Measurements and approved by the AIEE Technical Program Committee for presentation at the AIEE Winter General Meeting, New York, N. Y., January 30–February 3, 1950. Scheduled for publication in AIEE *Transactions*, volume 69, 1950.

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code appears on the contacts on the number-mixer relay where it is read by the teletype transmitter and transmitted to the printer. The space function is also inserted at the proper time by means of a relay controlled by the print-sequence control.

TIMING SEQUENCE

The timing of some of the more important events in the printing sequence is shown in Figure 2. The upper row (*a*) shows the teletype codes transmitted during the starting interval, the printing interval, and the stopping interval. The selection of events is controlled by either the master switch or the circuit selector switch. The controlling element is shown as curves (*b*) and (*c*) of Figure 2. Following the sequence of events, the start of the master switch puts out a blank interval to start the printer, and then cuts in the circuit selector and waits until the circuit selector has reached home position. During this interval no codes are transmitted. When the circuit selector reaches home position, control reverts to the master switch which then transmits carriage return and figures functions to insure that the printer is in a starting position at the left side of the page and in condition to print numbers. Control again returns to the circuit-selector switch and remains there for the remainder of the printing interval. At the end of the printing interval control reverts to the master switch which, in turn, transmits the carriage return, line feed, and stop function codes. The machine then turns off at both the measuring and printing ends.

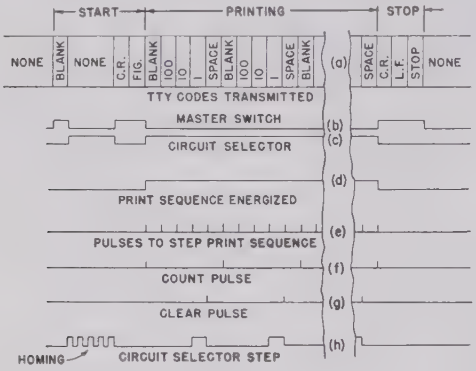


Figure 2. Time relations of events in printing sequence

C. R.—carriage-return function; L. F.—line-feed function; FIG.—figures function

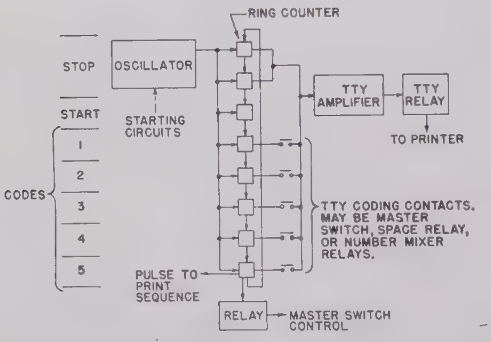


Figure 3. Diagram showing operation of teletype transmitter

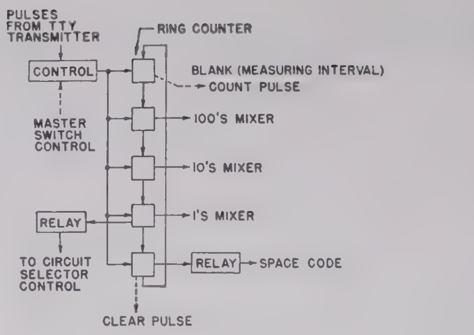


Figure 4. Block diagram of essential features of print-sequence control

Unit is triggered by pulses received from the transmitter; these pass through control circuit before reaching print-sequence tubes

Curve (*d*) of Figure 2 shows that the print-sequence control is energized only during the printing interval. This prevents any of the print-sequence functions from interfering with the framing functions as determined by the master switch. The pulses which step the print-sequence control are shown as curve (*e*) of Figure 2. Curve (*f*) shows that a pulse to the step voltmeter occurs at the beginning of the blank interval of each printing cycle. This blank interval provides a time interval for the step voltmeter to make the measurement. It is 0.16 second in duration. As indicated by curve (*g*), a clearing pulse is transmitted to the various counters at the beginning of the space interval to remove the previous count from the counters before a new count is received. Curve (*h*) of Figure 2 shows when the circuit selector steps. During the homing interval it steps rapidly until it reaches home. During the remainder of the printing cycle it steps at the beginning of the space function.

SYSTEM COMPONENTS

Teletype Transmitter. Figure 3 is a block diagram containing the essential information on the operation of the teletype transmitter. The principal component is a tube arrangement which acts like a ring counter of eight tubes operated one at a time under the control of an oscillator. The first two tubes of the ring counter generate a marking interval for the teletype printer and the next tube generates a spacing interval. These are similar to the standard marking and spacing intervals used for synchronizing the printers. The remaining five counting tubes are used for generating the coding pulses for the teletype printer. The code pulses pass through contacts of the number-mixing relays or the master switch, which allow the proper codes to pass to print the information or function desired at that point in the operation sequence. The coded pulses are mixed with the stop and start codes generated by the first three tubes of the ring counter and passed to an amplifier which in turn controls the transmitting relay. On the contacts of this relay appear normal teletype pulses used for control of the telephone-line circuit connecting to the printer. Although a mechanical transmitter could be used in place of the electronic transmitter outlined, the need for auxiliary control pulses to operate other electronic equipment makes an electronic pulse generator more desirable than a mechanical one. This is due to the difficulty of obtaining mechanical contacts with no chatter or bounce. An electronic pulse is derived from the tube which generates the fifth code im-

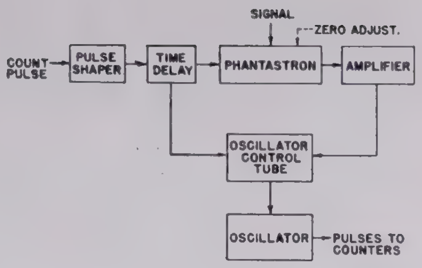


Figure 5. Block diagram of step voltmeter

Step voltmeter performs actual measurement during the blank interval of the print sequence

pulse to operate a relay which in turn steps the master switch and in addition provides a pulse to step the print-sequence control.

Print-Sequence Control. The print-sequence control operates in a manner analogous to that of the transmitter. However, it contains only five counters in the ring instead of eight. It is triggered by the pulses received from the transmitter. These pass through a control circuit (operated by the master switch) before reaching the print-sequence tubes in order that operation can occur only during the printing interval. Figure 4 shows a block diagram of the essential features. As the ring counter steps, various auxiliary conditions are controlled. The blank interval is provided to permit time for the measurement. If three digits are to be printed the tubes of the 100's mixer are energized. The next step energizes the 10's mixer, the fourth step energizes the 1's mixer and also the auxiliary relay, which energizes the coil of the circuit-selector stepping relay. In the fifth step the circuit-selecting relay moves to the next position. At the instant the print sequence is transferred to the first step, a pulse is transmitted to the step voltmeter, giving the command to make a measurement.

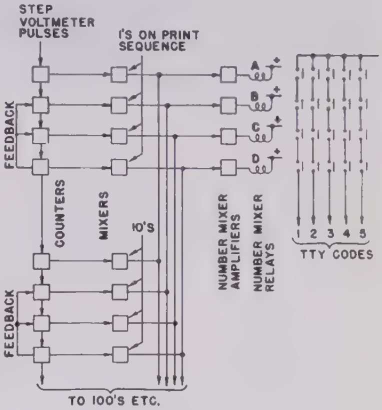
The Step Voltmeter. The actual measurement is performed during the blank interval of the print sequence by the step voltmeter, shown in the block diagram of Figure 5. On receipt of the count command pulse from the print sequence control, a pulse is generated by the pulse shaper which in turn causes the time delay tube[3] to function. The time delay tube does two things. It starts a phantastron,[3] and it also operates the oscillator control tube to hold the oscillator in an off position. At the end of the delay interval the oscillator control tube turns on the oscillator. Meanwhile, the phantastron has been started, and it runs for a time interval determined by the d-c signal voltage applied to its plate. It operates through an amplifier to turn the oscillator control tube off. As the oscillator runs, a number of pulses will be generated proportional to the voltage being measured. The zero set is a voltage introduced into the phantastron to permit its running time with no signal to exactly equal the time-delay interval, and thus, with no signal, the oscillator never starts.

Counting and Number Mixer. The pulses obtained from the oscillator are counted by four-tube binary counters arranged in decades.[4] As many decades are provided as are required by the digits needed. Figure 6 indicates the general arrangement. The number mixer permits the selection of the proper digit as commanded by the print-sequence control and, in addition, as determined by the count existing in the selected decade of the counters. Voltages from the mixer operate through the number-mixer amplifier to operate the number-mixer relays. It can be readily seen that with four relays ten possible contact arrangements can be provided. These contacts therefore set up the teletype codes required for each digit from one to zero. Figure 7 shows the relays operated for each number from zero to nine.

Arrangement of Components. A complete machine is shown in Figure 8. This machine, in addition to performing the functions outlined previously, also will accumulate totals, shift ranges, and print on two machines. Two machines were required since the user desired more columns than were available on one machine. This can be carried as far as desired. In the rack from top to bottom are located a control panel, the tube circuits, the transmitting relays, the circuit selecting relays, and the power supply. Although the teletype machines are shown alongside the rack, they may be located at any distance provided a satisfactory communications link is used for interconnection.

Figure 6. General arrangement of number mixer

Number mixer permits the selection of the proper digit as commanded by the print-sequence control and as determined by the count existing in the selected decade of counters



A section of one of the log sheets obtained from one of the machines during a test period is shown as Figure 9. The machine was designed to read current in the outgoing lines of a distribution center and to accumulate totals for zone loads. The vertical columns are the readings in tens of amperes for a given line or total and the horizontal readings were made automatically once each half hour. In this particular case the form for the log sheet is preprinted. Approximately 20 vertical columns can be printed on a page. Such features as automatic page advance at the end of the day can be readily obtained. These readings were made at the control center of the supervised distribution substation.

Figure 7. Relays operated from each number from zero to nine

DIGIT OR FUNCTION	RELAYS OPERATED	TTY CODE				
		1	2	3	4	5
1	DA	•	•	•		•
2	DB	•	•			•
3	DAB	•				
4	CD		•		•	
5	ACB					•
6	BCD	•		•		•
7	ABCD	•	•	•		
8	BC		•	•		
9	ABC				•	•
0	D		•	•		•
C.R.	MASTER SW.				•	
FIG.	MASTER SW.	•	•		•	•
L.F.	MASTER SW.		•			
STOP	MASTER SW.			•		•
SPACE	SPACING			•		

The usefulness of this instrument is most apparent on any continuous flow processes, such as electric power generation

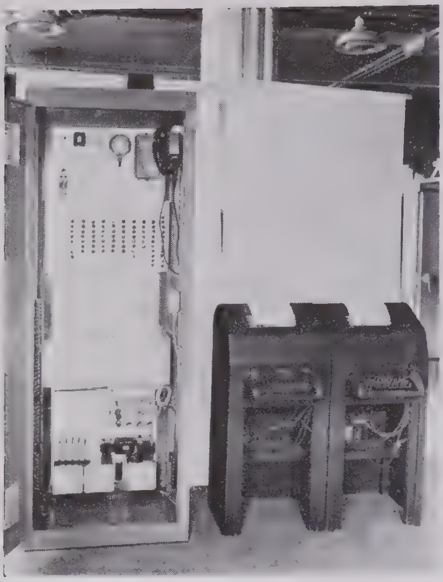


Figure 8. Rack and two printers producing 40 columns with totals and subtotals

Located in the rack, from top to bottom, are a control panel, the tube circuits, the transmitting relays, the circuit selecting relays, and the power supply. Teletype machines alongside rack may be located at remote point

and transmission, gas transmission, oil storage or transmission, steel making, paper making, oil refining, chemical processes, and so forth. A portable type can be used in testing new installations. The readings of many different quantities related to the process such as time, temperature, pressure, flow, voltage, current, counting, integrated flows, and so forth, may all be assembled in a related manner on a single instrument and on a single log sheet. The record may be made at the most essential point whether feet or miles intervene. It is particularly useful in those operations which are fully automatic or where the man power which is available is low, or where it is desirable to lower the man power.

The use of this instrument permitting the elimination of the human element results in a more accurate and legible record. All readings are taken as scheduled either by clock contacts or by some element of the process whether or not the operator is busy on other duties.

Where records are used in more than one office for various purposes the instrument will produce up to 20 good carbon copies. Copies containing vast amounts of data are readily mailed or stored. If more than 20 copies are required, a ditto carbon or ribbon may be used and up to several hundred copies may be obtained. In addition, if readings must be obtained at two or more locations, as many additional printers as desired may be used.

GLENWOOD SUBSTATION
LOCATION

LINE CURRENT AND GROUP TOTALS
MULTIPLY BY 10 FOR AMPERES

NO. / TIME	01	02	03	04	TOT	05	06	07	08	TOT	09	10	11	12	TOT	13	14	15	16	TOT
12:30	13	25	38	29	105	28	37	17	28	110	43	30	34	33	140	44	26	37	25	132
1:00	13	25	39	29	106	27	35	16	27	105	42	29	33	32	136	42	25	36	24	127
1:30	12	24	37	27	100	27	35	16	27	105	41	29	33	32	135	41	25	35	24	125
2:00	12	23	35	27	097	25	33	15	26	099	39	28	32	31	130	40	24	34	23	121
2:30	11	21	33	25	090	24	32	14	24	094	37	26	30	29	122	38	23	32	22	115
3:00	11	21	32	24	088	23	30	14	23	090	36	25	28	28	117	36	22	31	21	110
3:30	10	20	31	23	084	23	29	14	23	089	35	24	28	27	114	35	21	30	20	106
4:00	10	19	30	23	082	22	28	13	22	085	33	23	27	26	109	34	20	29	19	102
4:30	10	19	30	22	081	22	28	13	22	085	33	24	27	26	110	34	20	29	19	102
5:00	10	19	30	23	082	22	28	13	22	085	33	23	27	26	109	34	20	29	19	102
5:30	10	19	30	23	082	22	28	13	22	085	33	24	27	26	110	34	20	29	19	102
6:00	10	19	32	24	085	23	30	14	23	090	36	25	28	28	117	36	21	31	21	109
6:30	11	21	32	24	088	23	30	14	23	090	36	25	28	28	117	36	22	31	21	110
7:00	11	22	33	25	091	24	32	15	24	095	37	26	30	29	122	38	22	32	21	113
7:30	12	23	35	27	097	26	34	15	26	101	39	28	31	31	129	40	24	34	23	121
8:00	12	24	37	28	101	27	35	16	27	105	41	29	33	32	135	42	25	35	24	126
8:30	12	24	38	29	103	28	36	17	28	109	41	28	31	32	132	42	25	36	23	126
9:00	11	22	33	25	091	25	32	15	24	096	38	27	30	29	124	38	23	32	22	115
9:30	11	21	32	24	088	23	30	14	23	090	35	25	29	28	117	36	22	30	21	109
10:00	10	19	30	23	082	22	29	13	22	086	34	24	27	26	111	34	20	29	21	104
10:30	12	23	35	26	096	26	34	15	25	100	36	26	30	30	122	38	22	33	22	115
11.00	14	27	42	32	115	31	40	18	31	120	48	34	38	37	157	49	29	41	28	147
11:30	14	28	44	33	119	32	42	19	32	125	49	35	39	38	161	50	30	43	29	152
12 00	11	22	34	26	093	25	33	15	25	098	39	27	31	30	127	39	23	33	22	117
12:30	11	22	34	26	093	25	33	15	25	098	38	27	31	30	126	39	23	33	22	117
1:00	13	25	39	29	106	28	37	17	28	110	44	31	35	34	144	44	26	38	25	133
1:30	13	25	39	29	106	28	37	17	28	110	44	31	34	33	142	44	26	37	25	132
2:00	14	27	42	31	114	30	40	18	30	118	47	33	37	36	153	48	28	40	27	143
2:30	14	27	42	31	114	30	40	18	31	119	47	33	37	36	153	48	28	40	27	143
3:00	15	29	45	34	123	33	43	19	33	128	50	35	40	39	164	51	30	43	29	153
3:30	15	30	46	35	126	33	44	20	34	131	52	36	41	40	169	52	31	45	30	158
4:00	15	30	46	35	126	33	44	20	34	131	52	36	41	40	169	53	31	44	30	158
4:30	15	30	46	35	126	34	44	20	34	132	52	36	41	40	169	53	31	44	30	158
5:00	13	25	38	29	105	28	37	16	28	109	43	30	34	33	140	44	26	37	25	132
5:30	13	25	38	29	105	28	37	16	28	109	43	30	34	33	140	44	26	37	25	132
6:00	13	25	38	29	105	28	37	16	28	109	43	30	34	33	140	44	26	37	25	132
6:30	13	25	38	29	105	28	37	17	28	110	43	30	34	33	140	44	26	37	25	132
7:00	15	31	48	36	130	35	46	20	35	136	57	40	45	44	186	58	34	49	33	174
7:30	16	32	51	38	137	37	48	22	37	144	57	40	46	44	187	58	34	48	33	173
8:00	16	33	51	39	139	37	48	22	37	144	57	40	45	44	186	58	34	49	33	174
8:30	16	32	51	38	137	37	49	22	37	145	57	40	45	44	186	58	34	49	33	174
9:00	16	31	47	36	130	34	45	20	34	133	53	37	42	41	173	54	31	45	30	160
9:30	15	29	45	34	123	33	43	19	33	128	51	36	41	39	167	52	30	44	29	155
10:00	15	29	45	34	123	32	41	19	32	124	49	35	39	38	161	50	29	42	28	149
10:30	14	27	41	31	113	30	39	17	30	116	46	32	37	35	150	47	27	39	26	139
11:00	13	26	40	30	109	28	38	17	29	112	45	31	35	34	145	45	26	38	25	134
11:30	13	25	40	30	108	28	37	16	28	109	43	30	34	33	140	44	25	37	25	131
12:00	12	24	37	28	101	27	35	16	27	105	41	29	33	32	135	42	25	36	24	127

Figure 9. Part of a log sheet obtained from a teletype machine during a test period

CONCLUSIONS

The Metrotype system for digital recording and telemetering is a measuring system which produces records in the form of columns for separate quantities, lined up automatically for time or some other factor. Transmission may be made any distance and may include totals or any other computation as required. The following are incidental benefits from the use of the Metrotype: greater accuracy, greater legibility, duplicate records, uniform timing of readings, and each reading distinct from all others.

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Rectifiers for Electronic D-C Motor Drives

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THE USE of rectifiers for d-c motor control is a natural development because of their ease of control, high speed of response, and use of all static components. The economics of d-c motor drive applications showed that 550 volts direct current would give the best return. Standard rectifier equipment has been developed which delivers 550 volts direct current directly from a 460-volt 3-phase power system by using a 3-phase double-way (full-wave) rectifier power circuit. The majority of d-c motor drive applications can be supplied from 150-kw, 300-kw, or 500-kw power units.

The basic elements of a typical electronic d-c motor drive system are shown in the one-line diagram of Figure 1. The a-c tie breaker allows the equipment to be operated from either of the two secondary a-c feeders. The d-c motor switches permit selection of different motor and rectifier combinations. A complete installation generally consists of one or more pairs of units connected in this manner.

Conduction in the sealed ignitron tubes is initiated once during each cycle by the firing of the ignitor, which establishes a cathode spot on the mercury pool. The conducting period of the tube will be reduced if the ignitor firing is delayed in time for an appreciable part of one-half cycle. The average value of the direct voltage output is correspondingly reduced. Thus the direct voltage is a function of the angle of phase retard of the ignitor firing.

The principal requirements of a d-c motor drive are

1. The armature voltage must be continuously adjustable from zero to maximum voltage.
2. The armature voltage be regulated.
3. The time of response in regulating be small compared to the inertia effects in the load.

These requirements are met by four groups of circuits. These are

1. The ignitor and excitation anode circuits.
2. The variable phase-shifting network.
3. The fixed phase-shifting circuit.
4. The amplistat and its signal circuits.

The ignitor circuit consists of a static-magnetic firing circuit which provides a high-voltage firing pulse once each cycle for each ignitor. The excitation anode and its circuit maintains the cathode spot which has been established by the ignitor.

The phase-shifting network shifts the phase of the input voltages to the ignitor and excitation anode circuits. This network provides a constant voltage output over the full phase-shift range so that the performance of the firing circuits is not affected.

The fixed phase-shift transformers are adjusted to bring the ignitor pulses into proper phase relation with their respective tube anode voltages.

The amplistat circuit is a magnetic amplifier reactor and its associated signal circuits. The output of the amplistat is a control current which varies the actual angle of phase shift of the excitation voltages. The amplifier circuit has extremely high gain and over-all characteristics similar to an electronic amplifier or an amplidyne unit. The amplistat has been selected for this type of rectifier equipment because it has physical and electrical characteristics similar to the firing circuit and phase-shifting circuit components. It uses static components and it has no filament. Thus it is possible to build into all portions of the excitation system the same degree of reliability and freedom from frequent component replacement and wear.

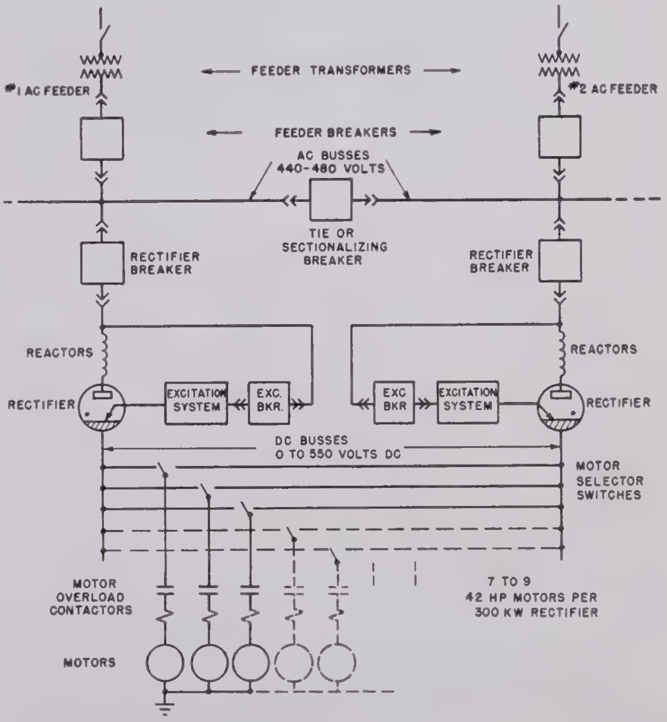

Figure 1. Typical electronic d-c motor drive system

The voltage-regulating requirement is met by the use of a closed-loop regulating system. The closed loop includes the power rectifier d-c circuit, the amplistat, the phase-shifting network, the excitation circuits, and back-to-the-power rectifier d-c circuit. The loop provides a continuous regulating function at any value of the power rectifier direct voltage.

Digest of paper **50-33**, "Rectifier Equipment for Electronic D-C Motor Drives," recommended by the AIEE Committee on Electronic Power Converters and approved by the AIEE Technical Program Committee for presentation at the AIEE Winter General Meeting, New York, N. Y., January 30–February 3, 1950. Scheduled for publication in AIEE *Transactions*, volume 69, 1950.

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System Performance With Motor-Driven Exciters

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THE MOTOR-DRIVEN exciter set consists of an induction motor directly driving an exciter, with, usually, added flywheel inertia. The exciter set may be one of a number of station auxiliaries on a bus which derives its power from either the main generator terminals through a transformer, from the external system through a transformer, or from a separate house generator (Figure 1). Under normal operating conditions or under emergency conditions resulting from the failure of an auxiliary power supply it may be necessary to transfer the station auxiliaries from one bus to another.

Calculations were made to determine the effect of exciter set and system parameters on the permissible throw-over time of the exciter motor from one power source to another and on the maximum permissible clearing time of a 3-phase short circuit at or near the main generator terminals. During these critical periods, excitation requirements are maintained by the field flux linkages of the generator field and the inertia of the exciter set, and permissible times are determined by the ability of the generator to retain stability with the system. Power input to the exciter motor was zero during both the throw-over and fault periods and was determined by the terminal recovery voltage of the generator after the completion of throw-over and fault clearing.

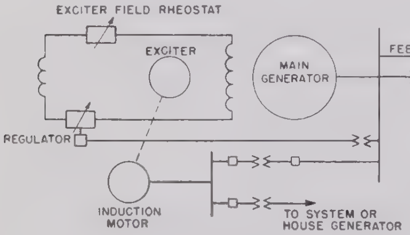

Figure 1. Line diagram of system indicating application of motor-driven exciter set

The maximum permissible throw-over time of a motor-driven exciter set with and without added inertia varies depending upon the initial operating conditions, the system parameters, and the type of main generator voltage regulator, as follows:

1. Without added inertia—1.5 to 6 seconds with $H=1.75$. (H, in kilowatt-seconds per kilovolt-ampere, $=0.231\ WR^2[\mathrm{rpm}]^2\times10^{-6}$ /base kilovolt-amperes
2. With added inertia—4 seconds to at least 10 seconds with total H of 5; 8 seconds to at least 10 seconds with total H of 10.

Appreciable gain in throw-over time is attained with:

1. Added exciter-set inertia; decreasing gain results with additional increases in inertia.
2. Increase in the size of the system (lower system reactance) connected to the main generator.
3. Increase in the size of the main generator with the resulting increase in open-circuit field time constant.
4. A unity or leading power factor load on the main generator (generator under-excited).
5. A high torque characteristic of the induction motor of the exciter set.

For short throw-over times, system steady-state conditions are best maintained with the generator operating under-excited and with regulator action.

For the short-circuit case, the following conclusions are reached:

1. Short-circuit clearing times of one to two cycles less than the critical switching times, based on constant generator field flux linkages, are possible for most conditions of operation.
2. Longer permissible switching times result with increase in the size of the system connected to the main generator and with main generators of higher inertia factors.
3. Slightly longer permissible switching times result with additional exciter inertia, voltage regulator action, and smaller loads of lagging power factor.

The emergency power transfer differs from a planned transfer where a synchronizing of the two power sources occurs and at no time is the exciter motor without power. The minimum time for an emergency throw-over is about one-half second and is determined by the ability of the mechanical switch in making the throw-over. This minimum time can impose a heavy, but safe, duty on the induction motor due to the trapped flux in the motor. Normal emergency throw-over times are generally between one and two seconds. This study indicates that for these throw-over times a very substantial margin in stable system performance exists with the use of a special design of motor-driven exciter set with an inertia constant H of 5 and a maximum torque of about 325 per cent of rated torque. This exciter set does not require a shorter throw-over time than any other essential station auxiliary. The high torque characteristic of the induction motor enables satisfactory system performance to be obtained with voltage at the motor terminals as low as 70 per cent of the normal voltage, both on steady state and on re-energization after throw-over.

For a 3-phase short-circuit fault at or near the generator terminals, the maximum permissible switching time with this exciter set closely approaches the actual critical switching times which vary between 11 and 20 cycles for most operating conditions with rated kilovolt-ampere output from the main generator. Practical switching times are generally below ten cycles.

Digest of paper **50-49**, "Excitation System Performance With Motor-Driven Exciters," recommended by the AIEE Committee on Power Generation and approved by the AIEE Technical Program Committee for presentation at the AIEE Winter General Meeting, New York, N. Y., January 30–February 3, 1950. Scheduled for publication in AIEE *Transactions*, volume 69, 1950.

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Analogue Computer for Flight Simulator

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IN THE FIELD of dynamics, problems concerned with aircraft motion are noted for their complexity. The ordinary differential equations which generally can be used to characterize the problems commonly are of order between 20 and 30 and, unless drastic assumptions are made, contain many nonlinear terms. Important nonlinear effects are introduced by the trigonometric effects associated with the motion of a rigid body with six degrees of freedom as well as by the nature of the aerodynamic forces and moments acting upon the aircraft. Also, if the aircraft is controlled automatically, the nonlinear properties of the controlling equipment are significant. The complexity of the problems is such that computing machines are required for their solutions.

Because of the fact that no machine was available well adapted to handle problems in this field, a generalized analogue computer has been developed for particular application to the solution of this type of problem. The machine is known as a flight simulator; however, in order to handle the diverse nature of aerodynamic problems, the computer had to be of such scope and flexibility that it is expected to have applications to other problems in the general field of dynamics.

The flight simulator was designed to apply specifically to aircraft problems of two general types: those problems that can be adequately represented by ordinary nonlinear differential equations with time-varying coefficients; and aircraft stabilization problems in which the control equipment is available and requires test, but the mathematical representation of which is either unknown or highly complex. The computer is arranged to handle problems of the first type in much the same way as existing differential analyzers. Problems of the second type are studied by employing an auxiliary device known as a flight table that orients the control equipment in a fashion similar to that occurring in actual flight. Signals from the control equipment are connected into the computer in a way analagous to that in which it is used in flight, thus permitting the control equipment to be tested under circumstances almost identical with actual flight conditions. Use of the simulator to test actual aircraft control components requires that it operate on a one-to-one time scale. Thus, if a particular phenomenon requires two seconds to occur in flight the same phenomenon must be computed by the machine in two seconds. The rapidity of occurrence of many flight motions required that special attention be paid to the speed of operation of the computer.

The variety of problems requiring solution led to the choice of an electric computer primarily to gain flexibility but also to obtain the necessary computing speed. The computer is of the a-c type, and dependent variables in the mathematical equations being studied are represented in the machine by 400-cycle-per-second voltages. The amplitude of the voltage is proportional to the magnitude of the variable being represented, and the phase of the voltage is either zero or 180 degrees depending upon the sense of the variable. The use of a-c signals in the machine provided freedom from grounding difficulties and permitted trigonometric transformations to be handled readily. Considerations such as speed of computations determined the frequency employed, and 400 cycles per second seemed to be the lowest frequency feasible. Phase shift in the signals was troublesome, and it was necessary to limit the phase shift introduced by each element of the computer to 0.05 degree. In addition, it was necessary to make use of quadrature rejection circuits.

The high speed of computation needed and the large number of effects that required representation made it necessary to develop almost all the various types of computing components used in the machine. These include summing networks, repeater amplifiers, multipliers, integrators, vector resolvers, and arbitrary function generators. Accuracy specifications on each computing element of 0.1 per cent of full scale output were met. The time constant associated with the operation of each computer element is about one millisecond except for operations such as summation and multiplication by a constant where, because of the frequency of occurrence of these operations, the time constant had to be well below 0.1 millisecond.

When the simulator is used to test flight control components, a servo-driven table must be employed to orient those components of the control system that respond to angular motions of the aircraft. The table that simulates the aircraft motion is called the flight table, and its design and characteristics are important considerations in the analogue computer. When the complete flight problem is studied the table must have three degrees of freedom in order to simulate the pitch and yaw as well as the roll motion of the aircraft.

The analogue computer has been in operation for about one year and has been used largely on trajectory problems although some aircraft stability problems have been solved. In the year's operation over 5,000 solutions to trajectory problems and several hundred solutions to stability problems have been computed by the machine. The problems were such that each solution would require 100 to 1,000 hours to solve manually with a desk calculator. A typical stability problem required 9 integrators, 10 vector resolvers, 20 summing networks, 20 multipliers, 30 coefficient potentiometers, and 70 repeater amplifiers.

Operation thus far has proven the value of the simulator to aircraft dynamics and related problems.

Digest of paper **50-48**, **"A Generalized Analogue Computer for Flight Simulation,"** recommended by the AIEE Committee on Computing Devices and approved by the AIEE Technical Program Committee for presentation at the AIEE Winter General Meeting, New York, N. Y., January 30–February 3, 1950. Scheduled for publication in AIEE *Transactions*, volume 69, 1950.

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New Electrical Engineering Building

University of Washington

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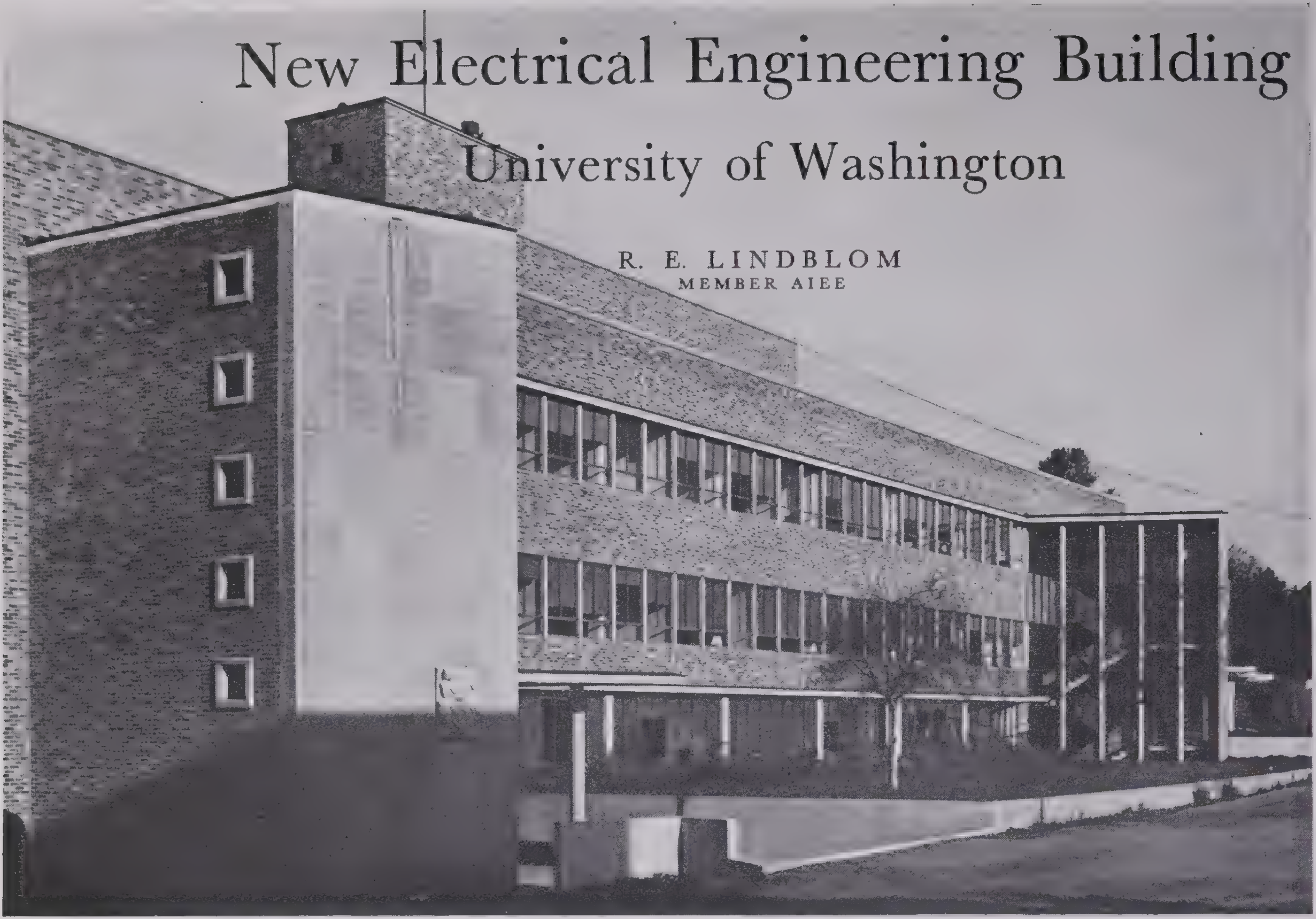

In April 1947 the University of Washington began construction on a new Electrical Engineering Building. The building itself was completed late in 1948 and the task of constructing and installing the equipment used for instructional purposes has been essentially accomplished. Features of the new buildings are the two major machinery laboratories and the radio and communications laboratory.

LATE IN 1948 construction was completed on a new Electrical Engineering Building for the University of Washington, Seattle. Built at a cost of nearly one million dollars, the building is a true example of functional design in every respect. It consists of three full floors with a total area of approximately 60,000 square feet.

The first floor is completely occupied by two major machinery laboratories, an industrial control laboratory, an oscillograph laboratory, a measurement laboratory, the upper level of an impulse generator laboratory, and various shops. These are all located about a large central meter room. The extra width of the building required for the machinery laboratories was provided on this floor by a cantilever beam ceiling construction which leaves a continuous row of windows on each side without column breaks. The two floors above narrow down to the standard economical width of a central corridor with a classroom on each side.

The radio and communications laboratory is located on the second floor with its own meter room. Communication between the two meter rooms is provided for by a spiral stairway and a dumb waiter. Various research rooms are also located on this floor. All power for the second floor is distributed from the radio laboratory switchboard.

On the third floor are located a transmission-line laboratory and an illumination laboratory, in addition to more research rooms. Power for all rooms on this floor is distributed from the transmission-line room switchboard.

Each staff member is assigned a private office measuring about 9 feet by 14 feet and the majority of the 22 offices are located at the front side of the building with an unobstructed view of Lake Washington and the Cascade Mountains. These offices face an open-end Engineering Quadrangle flanked on one side by the new Civil Engineering Building and soon to be flanked on the other by a new Mechanical Engineering Building. In addition to 12 classrooms, the Electrical Engineering Building has a modest size library and study room, a staff conference room, and a student activities room.

The upper floor switchboards are fed from the first-floor main power laboratory switchboards through 20-inch-thick hollow concrete block walls along each side of the corridor.

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The second and third floor switchboards are accessible for either front or rear servicing, since they are mounted directly in the hollow wall and are equal in depth to the wall. The hollow walls also serve for the ventilation ducts.

Water, air, gas, and electrical service to both second and third floor rooms is available through two large panel-covered conduit ducts located in the ceiling of the second floor. These ducts run the full length of the building. Holes in the second floor ceiling directly above the duct give access to all rooms on the third floor so that present classrooms may be converted to laboratory or research rooms.

A partially excavated basement area provides for the lower level of the impulse generator laboratory, a large storage area, a building service room, a combined generator and transformer room, and a battery room. A penthouse faces out on the roof where provision has been made for mounting various radio towers. A 3,200-pound-capacity freight elevator goes to all floors.

A separate 2,300-volt supply branching off from the main line into the building furnishes all power for experimental work. This line feeds into the basement generator and transformer room, which is centrally located directly under the first-floor main power laboratory switchboards.

Two 75-kva 3-phase air-cooled delta-delta-connected transformer banks step voltage down to 110 and 220 volts, respectively. Each bank is grounded at one corner of the delta on the low side. Two identical 3-unit motor-generator sets provide 3-wire 125–250-volt direct current to the d-c and a-c power laboratories, respectively. The driving motors are rated 150 horsepower, 2,300 volts, 1,800 rpm, and are push-button-controlled from the first floor switchboards. The generators are each rated 50 kw, 125 volts. An auxiliary 3-unit motor-generator set is available for standby use, and the circuits are so arranged that the entire building can be supplied, if necessary, from this source. Interlocking switches prevent parallel connection of generators. A 500-volt d-c generator is also located in the generator room and is push-button controlled on the first floor switchboard. By means of transfer leads going to all laboratories in the building, this power may be trunked to any location. A tap into the field circuit enables voltage control at the point of use.

Figures 1 and 2 show the d-c and a-c power machinery laboratories, respectively. Space is provided for 14 working parties in each laboratory. Two spaces are considered as standby, which would normally leave 12 available for use. With three persons per party, it is thus possible to handle two classes of 18 students each simultaneously.

In the d-c power laboratory a standard set of four machines is available to a working party. Two of these are identical 5-kw 125-volt compound-wound d-c generators; the third machine is a 20-horsepower 230-volt d-c motor, and the fourth machine is a 5-horsepower 115-volt d-c series motor. By means of special coupling devices all machines may be coupled as desired. With this set of four machines practically all types of experiments on d-c machinery can be performed. The machines, all mounted on a common

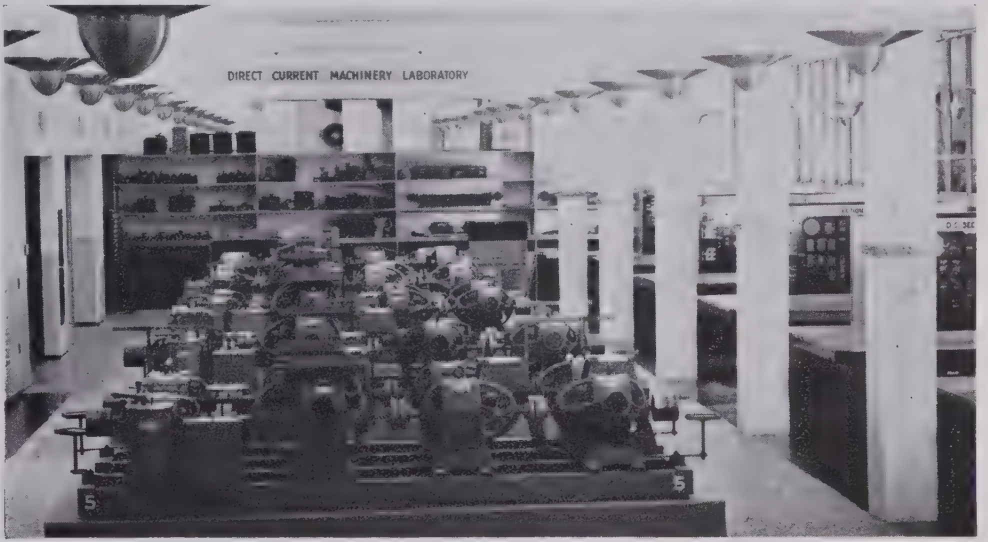


Figure 1. The d-c power machinery laboratory

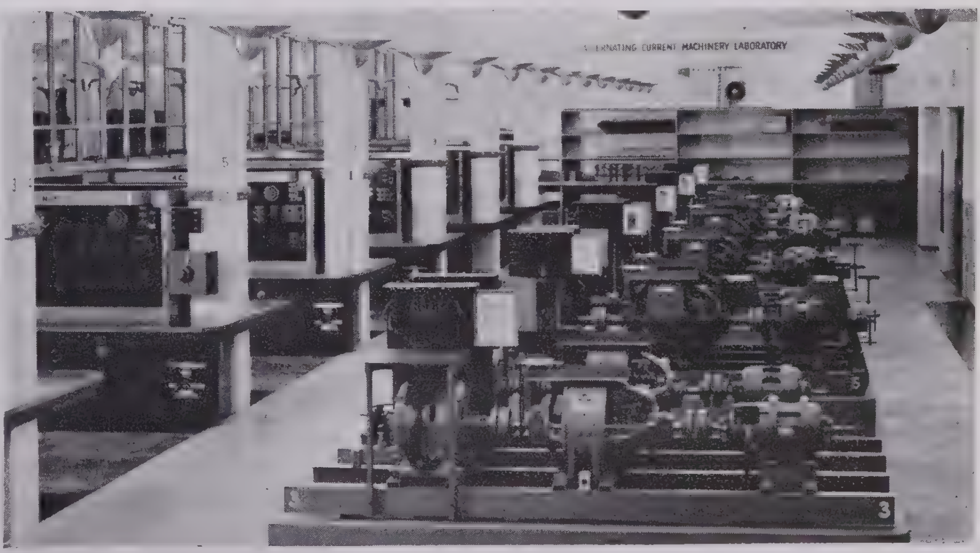
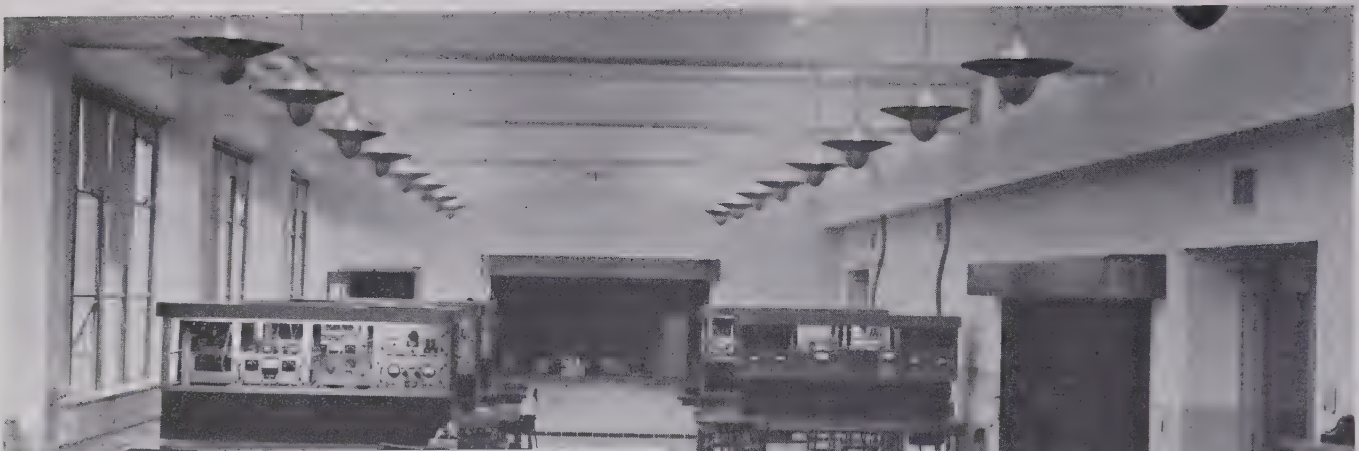


Figure 2. The a-c power machinery laboratory



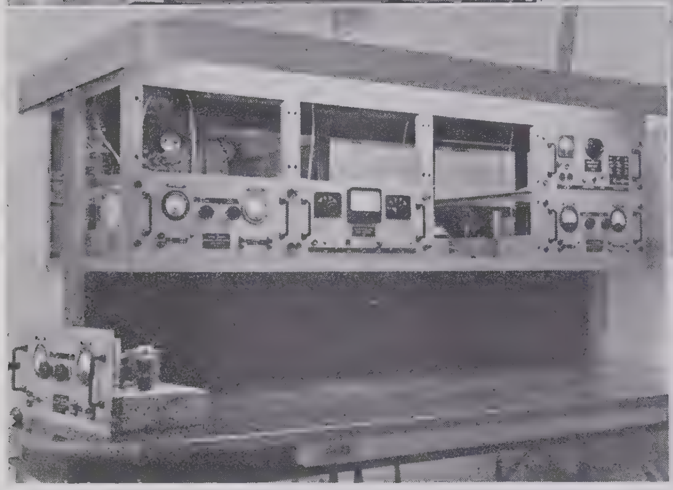


Figure 3 (above). The radio and communications laboratory

Figure 4 (left). Close-up of radio and communications laboratory working station

base, have their leads terminated at a test panel as shown in Figure 1. These stations are back to back and the space between is utilized for mounting four loading units that are available, two to each test panel. Mounted also on the test panel are power outlets from the main switchboard, control switches, and starting box terminals. Leads for making power and meter connections are stored in a rack that is mounted under the windows between test panels.

In the a-c machinery laboratory, shown in Figure 2, three machines are available to each working party: an 11-kva a-c generator, a 15-horsepower d-c motor, and a $7^1/_2$-horsepower induction motor.

Alternate test panels have wound-rotor induction motors while the others have squirrel cage rotors. The a-c generators have double terminal boards. One of these is wired so that various circuit arrangements can be made according to a nearby mounted diagram. The second terminal board is exposed when the first one is turned down, and its connections are scrambled for use in a phasing-out experiment. The a-c machinery laboratory test panels are longer than those of the d-c laboratory because of the need for three loading units at each station when doing certain 3-phase experiments. Figure 2 shows how additional switches, field rheostats, synchroscopes, synchronizing lamps, voltage regulators, frequency meters, and so on may hang from the corner of the test panel (see station *5*).

Special equipment such as rotary converters, rototrols, amplidynes, and apparatus that is less often used is mounted on casters and stored in the basement when not in use.

Two special motor-generator sets located in the battery room are controlled from a panel in the machine shop for charging batteries. One is 40 volts, 150 amperes capacity, and the other is 150 volts, 40 amperes capacity. These sets are normally used for charging a 32-volt lead battery and a 125–250-volt Edison battery, but by transfer circuits their outputs may be trunked to any place in the building.

Figure 3 shows the radio and communications laboratory on the second floor. Special equipment built for this laboratory consists of ten working stations built back to back as shown in Figure 4. Standard-size removable panel units can be installed to provide all types of voltage supplies and testing equipment needed in communications experiments.

Figure 3 clearly shows the ceiling conduit duct mentioned previously. The 20-inch-thick hollow corridor wall is also plainly indicated. The switchboard front is flush with the inside wall. All switchboards, as well as test panels, are lighted by fluorescent lamps. The main lighting is by indirect 500-watt units. In the two machinery laboratories the total ceiling lighting requires 50 kw. All laboratories, offices, and classroom ceilings are acoustically treated.

An outstanding feature of the building's construction was the fact that the entire design, construction, and installation of all electric equipment used for educational purposes was given over to the Electrical Engineering Department. This assignment involved the design of all switchboards, conduit ducts, testing panels, and machine sets. With a working fund of $70,000 available, $50,000 of which was used in the purchase of the main switchboards, the main motor-generator sets, and 35 machines, materials were purchased for completing the job. All equipment such as test panels, conduit ducts, loading units, lead racks, and machine bases were fabricated in the department's own shops. More than 6,000 feet of 2-inch conduit were used and more than 100,000 feet of wire were pulled in and connected.

Generator Rating of Induction Motors

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BECAUSE the induction generator has many advantages, it is desirable to consider what changes must be made, if any, in order that an induction motor may be operated satisfactorily as a generator. If the speed is driven above synchronism by the same number of revolutions that the machine normally operates below synchronism, the generator will deliver approximately rated current at rated voltage and rated efficiency. The electric power output will equal approximately the rated shaft motor power. The generator power factor will equal approximately the motor power factor times the motor efficiency.

The equivalent circuit, shown in Figure 1, has been developed to compute generator characteristics. It shows the stray load branch correctly represented for both motor and generator operation.

The conductance of the load and friction component is $G_L = s/R_2(1-s)$, where R_2 is approximately $R_{DC}(1+|s|/9)$. The conductance of the stray load component is $G_s = G_3(s^2+\Upsilon_c^2R_2^2)$.

The power lost in R_2 is $P_2 = I_2^2R_2$. The power lost in G_s is $P_s = I_2^2G_s/(G_s+G_L)^2$. The motor power delivered to G_L is $P_L = I_2^2G_L/(G_s+G_L)^2$. The air-gap torque, which is P_L divided by the speed, can be conveniently separated into two components: $T = P_2G_L/s(G_s+G_L) - P_s/(1-s)$. The first is the slip-frequency torque produced by the rotor resistance loss. It is reduced slightly by the ratio of the useful G_L to the total rotor G. The second term is the stray-load torque, which is associated with the actual rotor speed, and not with the slip speed. It is negative because it acts as a magnetic drag on the rotor, similar to a windage torque. Above synchronous speed, both terms are negative.

The approximate gross changes when using a 1,000-horsepower class-*A* induction motor as a generator can be followed with the aid of the equivalent circuit shown in Figure 1, and the approximate vector diagram in Figure 2. The primed symbols refer to full-load motor operation, and the double-primed symbols to full-load generator operation. The terminal voltages, $\boldsymbol{V}_t'$ and $\boldsymbol{V}_t''$, are equal in magnitude, but are shifted in phase with reference to the internal generated voltage. Figure 2 is drawn for equal rotor currents, so that $\boldsymbol{I}_2'$ and $\boldsymbol{I}_2''$ are equal in magnitude, and θ_2'' is equal to θ_2'.

It can be seen that the motor-generated voltage is less than the terminal voltage, whereas the generator internal voltage is greater than the terminal voltage by the current-impedance drop in the primary. Therefore, in changing from motor to generator action, the internal flux will increase, because the generated voltage has increased in magnitude by twice the in-phase component of the primary voltage drop. This is shown in Figure 2. Since for the same rotor current the generator flux is greater than the motor flux, slightly less slip is required.

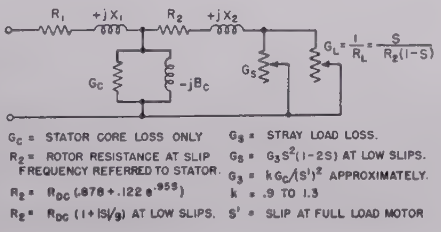
R₁
+jX₁
R₂
+jX₂
Gc
-jBc
Gs
$G_L = \frac{1}{R_L} = \frac{S}{R_2(1-S)}$
Gc = STATOR CORE LOSS ONLY
R₂ = ROTOR RESISTANCE AT SLIP FREQUENCY REFERRED TO STATOR.
R₂ = RDC (.878 + .122 e^.95S)
R₂ = RDC (1 + |S|/9) AT LOW SLIPS.
Gs = STRAY LOAD LOSS.
Gs = G₃S²(1-2S) AT LOW SLIPS.
G₃ = kGc/(S')² APPROXIMATELY.
k = .9 TO 1.3
S' = SLIP AT FULL LOAD MOTOR

Figure 1. Exact equivalent circuit for calculating the characteristics of a synchronous motor operated as a generator

$-s''/s' = 1-2s'$

The generator stator current is slightly less than for motor action, because it is reduced vectorially by two times the stator core loss current. Because of small angle shifts in the voltage vectors (not shown in Figure 2), the actual current change is only one-half of this approximate value.

$I_1''/I_1' = 1-\cos(\theta_0+n)\ [\cos(\theta_1'+2n)]2I_0/I_1'$

$I_0/\underline{\theta_0}$ is the line current at synchronous speed.

$I_1'/\underline{\theta_1'}$ is the line current for full-load motor operation.

$n = 0.87\ R_1/X_c$ radians.

The effect of all these changes is to give a net increase in the magnitude of the losses when shifting from motor to generator action of only two per cent of the losses for a 1,000-horsepower generator (five per cent of the losses for ten horsepower). The cooling, however, due to the increased speed, is approximately three per cent greater (six per cent for ten horsepower), and therefore the temperature rise is essentially the same or slightly less, for equal rotor currents.

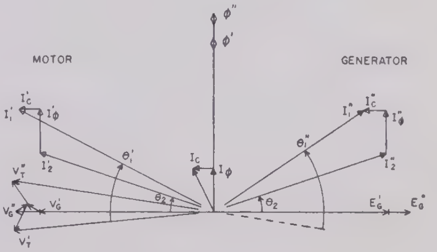

Figure 2. Approximate vector diagram of a synchronous motor operated as a motor and a generator

Small details are greatly exaggerated

The shaft torque is proportional to the square of the rotor current and inversely proportional to the slip. The speed increase due to the change in action is twice the slip. The generator power input is the product of the shaft speed and torque.

If operated at nameplate terminal current, the generator rotor current and the total losses would increase measurably, but the cooling of the generator would only increase slightly. The temperature would go up quickly, so that previous knowledge of the correct operating current is extremely important for proper operation.

Digest of paper **50-20**, "Generator Rating of Induction Motors," recommended by the AIEE Committee on Rotating Machinery and approved by the AIEE Technical Program Committee for presentation at the AIEE Winter General Meeting, New York, N. Y., January 30–February 3, 1950. Scheduled for publication in AIEE *Transactions*, volume 69, 1950.

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Insulation Levels Governed by Lightning Arresters

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INSULATION levels for transformers and circuit breakers for high voltages, to be economical, should be selected so that basic impulse insulation levels are as low as are feasible. Presently recognized basic insulation levels are too conservative for the grounded-neutral higher voltage systems. Available levels should be of such values that the user can select a level that is practical and economical for his system. If wide gaps exist between available levels, the user may find it to his economic advantage to depart from standards.

It is logical to base insulation levels on the levels to which a protective device, such as lightning arresters, can limit lightning surges. In order to provide such an application, the user must determine the nature of transient voltages that occur on his system and the probability of such transients resulting in failure of station equipment or of the protective devices. The minimum insulation level to which station equipment can be designed using lightning arrester protection includes the following requirements:

1. A margin between the voltage rating of the system (line-to-ground for grounded-neutral equipment) and the voltage rating of the lightning arrester.
2. The voltage difference between the lightning arrester rating (converted to crest voltage) and its surge discharge voltage (protective level).
3. A margin between the protective level of the lightning arrester and the insulation level of the equipment.

In order to arrive at an adequate but not excessive margin for the first item, the user must balance a degree of risk with the cost of equipment. There may be instances where it is considered a good risk to reduce this margin to the point where occasional lightning arrester failure can occur if basic insulation levels can be reduced in proportion with proportionate saving in first cost.

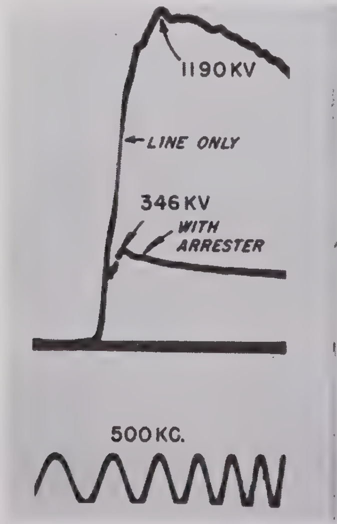

Figure 1 (left). Voltage waves at station end of line caused by a surge a mile away from the station with and without a station-type lightning arrester in the circuit

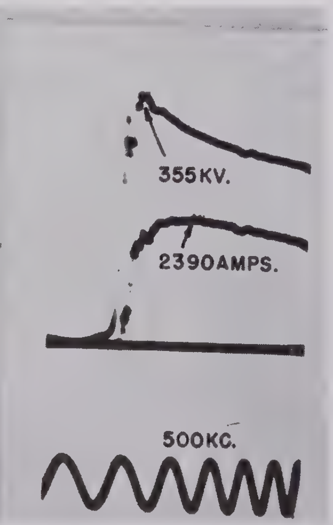

Figure 2 (right). Voltage and current of a lightning arrester for a test similar to that of Figure 1

The second item is fixed by lightning arrester characteristics, and any increase in insulation levels that may be necessary because of this difference must be charged to the use of lightning arresters as the basis for establishing insulation levels. The third item provides an estimated margin of protection to insure against unknown hazards.

Stations of the Bonneville Power Administration transmission system are protected from direct strokes with ground wires extending a mile on 230-kv lines and one-half mile on 115-kv lines. Station equipment is not expected to be subjected to direct strokes, and lightning arresters are used in the larger stations to provide a protective level for traveling waves due to hits on the conductor beyond the protective ground-wire area. Such surges are limited by the insulation level within the ground-wire area so that the current in the most severe surges that reach 230-kv equipment cannot exceed about 3,500 amperes.

With reduced insulation levels, it is imperative to know the protective levels that will be provided by protective devices for conditions on the system to which they are applied. Therefore, tests of lightning arresters were conducted by the Bonneville Power Administration for which the laboratory facilities of the Ohio Brass Company were leased. A mile-long line was constructed for these tests in order that surges might be applied approximating conditions that exist on the Bonneville system. Tests were made on assembled station- and line-type lightning arresters for 115-kv grounded-neutral systems. Station-type lightning arresters had a seal-off voltage rating of 97 kv, and the line-type 90 kv.

Figure 1 illustrates the voltage wave recorded at the open (station) end of the line from a surge impressed on the line a mile away, as well as the voltage level to which a station-type lightning arrester limited this surge. For conditions on the Bonneville system it is apparent that this 80 per cent arrester could adequately protect a basic insulation level of 80 per cent of the full-rated level for 115-kv service (full rated basic insulation level = 550 kv; 80 per cent = 440 kv; lightning arrester protective level = 350 kv). If ratings can be reduced, basic insulation levels can be reduced in proportion with a proportionate savings in first cost.

Figure 2 illustrates the voltage and current of a lightning arrester for a test similar to that of Figure 1. The current reaches its crest in about two microseconds indicating that for tests of this nature traveling waves are more severe than the 10/20 current waves of present standards.

Digest of paper **50-14**, "Lightning Arresters as a Criterion for Insulation Levels," recommended by the AIEE Protective Devices Committee and approved by the AIEE Technical Program Committee for presentation at the AIEE Winter General Meeting, January 30–February 3, 1950, New York, N. Y. Scheduled for publication in AIEE *Transactions*, volume 69, 1950.

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Rectifier-Type Power for Railroads

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Rectifier-type motive power is becoming more and more important in railroad electrification. Through its use, advantage can be taken of high-voltage trolley wires to transmit large quantities of power long distances. The rectifier motive power unit has simplicity and flexibility of voltage control and high accelerating horsepower at high speed.

TESTS on rectifier motive power equipment which have been announced recently[1] constitute a very important development in the electrification of steam railroads. Not only does this development mark another important step of progress in the use of electric energy as motive power on railroads, but it forms another practical demonstration of the inherent flexibility of the single-phase a-c system for railroad electrification.

The chief advantage of present d-c electrifications lies in the use of d-c series traction motors on the motive power units.

The fundamental advantage of the single-phase a-c system is its ability to use a high-voltage trolley wire, thus making it possible to supply, economically, large blocks of power over long distances for heavy concentrations of traffic.

Three types of motive power units have been built to operate from an a-c system, namely, the a-c series-motor type, the split-phase type, and the motor-generator type.

The a-c series-motor motive power unit is well adapted to any application. The best present-day examples of a-c series-motor locomotives are the Pennsylvania Railroad Class *GG1* and the New York, New Haven, and Hartford Railroad Class *EF3*. Although these locomotives are officially rated at 4,620 continuous horsepower, each can deliver from 8,000 to 9,000 maximum horsepower if occasion arises. These ratings are outputs at the rail. Output which is in excess of the continuous rating can be delivered at the rail over the entire speed range of the locomotive.

Another important asset of the a-c series-motor motive power unit lies in the simplicity and flexibility of the locomotive control system; that is, voltage control, which means a minimum of accelerating losses, a minimum peak power demand, and a very large number of running speeds.

The motor-generator motive power unit combines all the advantages of the flexible high-voltage single-phase a-c trolley system and the advantages of the d-c traction motor with the simplicity and flexibility of voltage control, but it does not have the ability to produce economically high short-time accelerating horsepower at high speed since the best proportions of the motor-generator set produce a motive power unit with constant horsepower characteristics. The rectifier motive power unit combines all the advantages of the high-voltage a-c trolley system with the simplicity and flexibility of voltage control plus the advantage of the d-c traction motor, and it has the ability to develop high accelerating horsepowers at high speed even more economically than is possible with the a-c series-motor motive power unit.

Thus, the rectifier motive power unit furnishes an attractive means of utilizing the power which can be delivered to it by a flexible high-voltage single-phase a-c trolley.

The advantages of rectifier motive power are summarized in the following tabulation:

I. RECTIFIER VERSUS SINGLE-PHASE SERIES-MOTOR MOTIVE POWER

A. The rectifier motive power unit has the following advantages on a 25-cycle trolley system. Some of these advantages will be increased if a 60-cycle trolley system is used.

1. Lower weight of equipment.
2. Less space required for equipment.
3. Higher running efficiencies and less standby losses.
4. Higher power factor.
5. Less maintenance. This point must be proved in service. However, the higher efficiency (which means less watt hours per ton mile) plus the reduced maintenance of the traction motor and gearing should easily overbalance the added maintenance of the rectifier equipment.
6. Superior tractive effort rating and tractive effort characteristics. Westinghouse standard diesel locomotive motor type *370-F* with 15/63 gearing on 42-inch wheels (65 miles per hour top speed) will develop 10,700 pounds tractive effort continuously up to 17.5 miles per hour. This is a much greater tractive effort and a higher speed than is possible with an a-c series motor. The speed-tractive effort characteristics of the rectifier motive power unit are similar to the speed-tractive effort characteristics of a motor-generator locomotive (they are flat) and hence should have the same antislip features now enjoyed by the motor-generator locomotive. The rectifier motive power unit can be applied safely at higher adhesions than is permissible for a-c series-motor motive power. The net result of these tractive effort advantages means that fewer axles will be needed for a rectifier motive power unit to meet a given duty cycle than will be needed for the single-phase series-motor motive power unit.
7. Rectifier motive power will develop its continuous horsepower rating at approximately 30 per cent of its top speed, whereas most a-c series-motor motive power units do not develop their continuous

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Full text of paper **50-81**, "Rectifier-Type Motive Power for Railroad Electrification," recommended by the AIEE Committee on Land Transportation and approved by the AIEE Technical Program Committee for presentation at the AIEE Winter General Meeting, New York, N. Y., January 30–February 3, 1950. Scheduled for publication in AIEE *Transactions*, volume 69, 1950.

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horsepower rating until they reach 50 to 60 per cent of top speed. This characteristic plus its ability to produce economically high accelerating horsepower at high speed makes rectifier motive power ideally suited for use either in freight or passenger service.

B. The rectifier motive power unit can be used under a 60-cycle trolley.

C. The rectifier motive power unit can be used interchangeably between two trolley zones involving:

1. Two frequencies, 25-cycles and 60-cycles.
2. Alternating current and direct current.

D. The rectifier motive power unit permits more horsepower capacity per cab than any other type.

II. RECTIFIER VERSUS MOTOR GENERATOR MOTIVE POWER

The rectifier locomotive has the following advantages:

1. Less weight of conversion equipment.
2. Less cost of conversion equipment.
3. Less space requirements for the conversion equipment.
4. More capacity per cab permitted.
5. Simpler and cheaper mechanical parts because of item 3.
6. Reduced standby losses and higher operating efficiencies.
7. High accelerating horsepowers at high speeds.

III. RECTIFIER VERSUS DIESEL-ELECTRIC MOTIVE POWER

The price of electric energy has remained relatively stable, whereas the long term trend of liquid fuel prices has been upward. Where economic conditions justify the electrification of a dieselized railroad, the diesel electric locomotives can be transformed into rectifier locomotives by removing the diesel engines and their appurtenances and applying pantographs, transformers, auxiliaries, and rectifier equipment. The rail horsepower rating of most diesel-electric locomotives can be substantially increased when and if such a change is made.

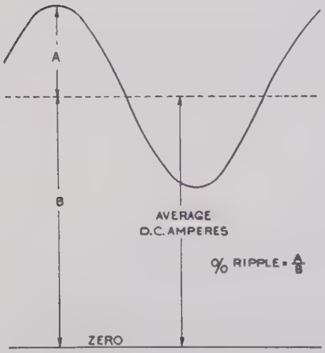


Figure 1. Ripple is the amount of deviation from a straight-line wave form of rectifier current

HISTORY

The desirability of producing a system of electrification embodying the advantage of high-voltage a-c transmission with low-voltage d-c traction motors has been a dream of transportation engineers ever since Westinghouse, in the year 1914, first ran a rectifier car in revenue service on the New Canaan branch of the New York, New Haven, and Hartford Railroad. This car was equipped with a multianode pumped-type rectifier. Two fundamental limitations were encountered in the use of this car as a motive power unit.

It was limited by the requirement of pumping to maintain the vacuum in the rectifier. At that time, the technique of vacuum pumping and vacuum seals had not reached the present stage of perfection.

The car produced telephone interference, and it was necessary to install track booster transformers in the test section to force all the trolley current to return through the rail.

Prior to 1937 all rectifiers were of the multianode pumped type, with as many as 18 anodes per tank. Subsequently, two developments, the sealed tube[2] and the ignitor, combined with a single anode, made the application of sealed-tube ignitrons to moving vehicles particularly attractive. With the great impetus which World War II gave to the production of aluminum and magnesium by the use of ignitrons, which supplied large amounts of d-c power, the ignitron was produced in quantity. Concurrently, the large demand for diesel-electric locomotives has similarly put the low-voltage d-c traction motor into mass production. Hence rectifier-type motive power becomes a product which will be benefited greatly by these two high-production items.

In the past, three main problems have deterred the use of ignitrons and other forms of rectifiers on rectifier motive power units:

1. The effect of shock and vibration encountered on a moving vehicle with respect to the strength of ignitron tube parts and with respect to the effect of a turbulent mercury pool on the performance of the ignitors.
2. The effect of the ripple in the rectified single-phase current wave form with respect to the heating and commutation of conventional d-c motors.
3. The effect of interference with communication circuits when operating from a single-phase trolley with ground return.

LABORATORY TESTS

Problem 1 was approached by determining the maximum values of acceleration forces expressed in terms of g (acceleration of gravity) observed on an electric locomotive classified as a satisfactory riding unit. These values were: maximum cab lateral observed, 0.66 g; usual cab lateral, 0.16 g. Both values were read on curved track at 95 miles per hour. Cycles of oscillation were 78 per minute.

Similar tests on another locomotive classified as an unsatisfactory riding unit indicated that the usual cab lateral was approximately 0.32 g while the frequency at 90 miles per hour was 114.

Based on these data, an oscillating test table was made on which the ignitrons were rigidly mounted. This table had an amplitude of vibration which could be varied from one to three inches and a frequency which could be varied up to 250 cycles per minute, giving values as high as 1.8 g acceleration, or well in excess of those observed on a rough-riding locomotive.

With this laboratory setup, two standard type *WL-653-B* ignitron tubes, mounted rigidly on the shaking table, delivered 200 to 800 amperes to a Westinghouse type *362* railway motor while shaking at a frequency of 120 cycles per minute and amplitude of one inch. This particular railway motor is standard on Westinghouse 660- and 1,000-horsepower diesel-electric switcher locomotives. At this shaking frequency no misfires occurred during several hours of operation. By a misfire is meant failure of the ignition circuit to start an arc for one or more half-cycle waves. One or several misfires in traction service would not be more serious than a pantograph bounce of short duration. This test was continued for several months, and no weakness was apparent in the design of the tube when exposed to these severe tests.

Problem 2 deals with the effect of ripple on commutation and heating of the traction motors. By ripple is meant the amount of deviation from a straight-line wave form of rectifier current. See Figure 1.

Tests on the type *362* motor were made at various loads and at various ripples in the power supply as affecting commutation. This motor is rated 510 amperes, continuous, on 310 volts. With a d-c circuit reactor to limit the ripple, the results of Table I were obtained.

Table I. Effect of Power Supply on Commutation

Voltage, Volts	Current, Amperes	Characteristics of Commutation
	With a 5 Per Cent Ripple	
315	500	Black
430	595	Black occasional pin point
430	638	Black
	With a 30 Per Cent Ripple	
290	300	Black
335	400	Black
375	500	Few pin points on one brush
406	600	Few pin points on one brush
425	650	Few pin points on one brush
	With a 75 Per Cent Ripple	
256	300	Almost black
290	400	Few pin points
320	500	Intermittent pin points on one brush
345	597	Black with intermittent pin points
358	670	Intermittent pin points

A temperature test was made on the type *362* motor using rectified current with a 30-per cent ripple. This test showed a temperature increase in the motor windings of from one to two per cent over the results obtained with generated d-c power.

Tests with rectified current were also conducted on two other traction motors, one a type *1447* used on the New York Board of Transportation subway cars and the other a type *559-DR3* used on the Long Island Railroad cars. Both of those motors showed equally as good commutation and stability as the type *362.*

Problem 3, pertaining to possible telephone interference, was studied in the laboratory. The type *362* motor was operated at 600 to 700 amperes with a single-phase ignitron. The harmonic content of the single-phase line current feeding the single-phase ignitron was measured by means of a harmonic analyzer.

In order to have a single-phase full-wave rectifier produce a square-wave alternating current, the following theoretical conditions are required:

1. Infinite inductance in the d-c circuit.
2. Zero angle of overlap.

This means that each half alternating current wave must be a square wave. The square a-c wave can be expressed mathematically by the Fourier series as follows:

$$e=\frac{4E}{\pi}(\sin \omega t+{}^1/_3 \sin 3\,\omega t+{}^1/_5 \sin 5\,\omega t\ldots\ldots+\frac{1}{n} \sin n\,\omega t) \qquad (1)$$

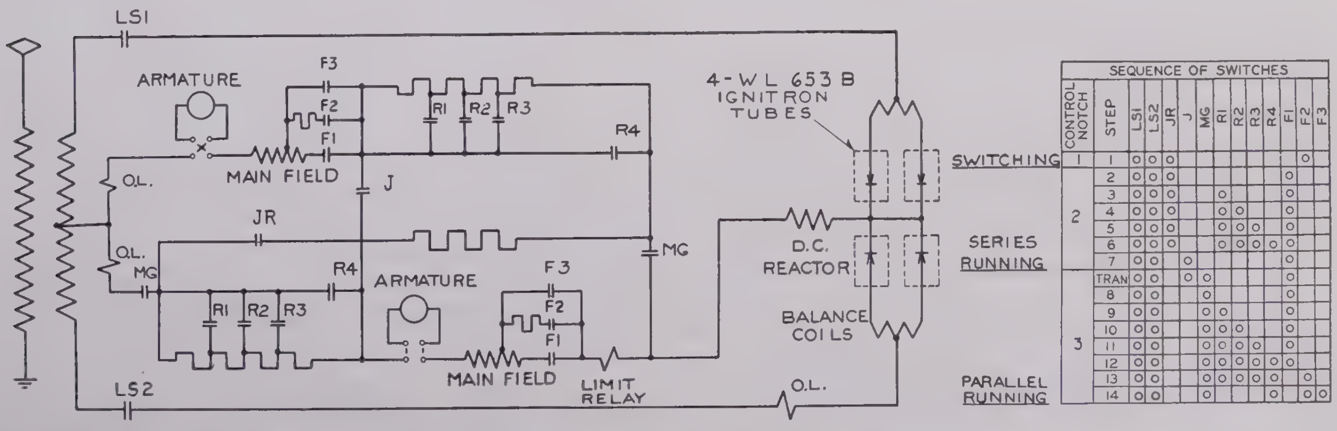
Where

e = instantaneous value of voltage
E = crest value of voltage
$\omega = 2\pi f$
f = fundamental frequency
n = any odd integer
t = instantaneous value of time

The term *IT* is used to indicate the intensity of telephone interference. Briefly, it is the product of current and *T*, a weighting factor which is dependent upon the frequency, coupling, and sensitivity of instruments and of the human ear.

The calculated *IT* product of a 25-cycle square wave having a 210-ampere fundamental is 165,000 based on the 1935 weighting. This is a very high value of *IT* and taken by itself would tend to discourage the use of rectifier motive power. However, it is not possible to obtain infinite inductance in the d-c circuit or zero angle of overlap in the a-c circuit.

In order to approach with practicable test equipment



SEQUENCE OF SWITCHES													
CONTROL NOTCH	STEP	LS1	LS2	JR	J	MG	R1	R2	R3	R4	F1	F2	F3
1	1	○	○	○								○	
2	2	○	○	○							○		
	3	○	○	○			○				○		
	4	○	○	○			○	○			○		
	5	○	○	○			○	○	○		○		
	6	○	○	○			○	○	○	○	○		
	7	○	○		○						○		
3	TRAN	○	○		○	○					○		
	8	○	○			○					○		
	9	○	○			○	○				○		
	10	○	○			○	○	○			○		
	11	○	○			○	○	○	○		○		
	12	○	○			○	○	○	○	○	○		
	13	○	○			○	○	○	○	○		○	
	14	○	○			○				○		○	○

Figure 2. Main circuit schematic diagram for the rectifier test car; electric equipment includes a specially designed transformer and four type-WL-653-B ignitron tubes for single-phase full-wave rectification

the theoretical square-wave conditions, all the available suitable inductance in East Pittsburgh for the d-c circuit was utilized, and the ignitrons were energized at a point where there was very little reactance in the power circuit. With this special setup, the maximum *IT* value obtained by test was approximately ten per cent of the calculated *IT* value.

With the aid of practicable filtering means, the *IT* value for a 210-ampere fundamental was reduced to 357.

Table II gives a picture of the various harmonic currents involved for the conditions in the preceding paragraphs.

Table II. Harmonic Currents for Various Values of IT

Harmonic	Frequency, Cycles Per Second	Calculated Square Wave-Current, Amperes	Test Current, Amperes (Dec 16, 1947)	Test Current, Amperes (Feb 3, 1948)
1	25	210	210	210
3	75	70	59.7	41.5
5	125	42	32.7	27.8
7	175	30	20.1	10
9	225	23.3	13.8	2.66
11	275	19.1	9.25	0.6
13	325	16.15	6.18	0.5
15	375	14	4.37	0.258
17	425	12.35	3.00	0.104
19	475	11.05	2.15	0.074
21	525	10.0	1.61	0.088
23	575	9.12	1.46	0.046
25	625	8.38	1.35	0.0142
27	675	7.77	1.21	0.0195
29	725	7.24	1.13	0.031
31	775	6.78	1.00	0.00565
33	825	6.37	0.84	0.0159
35	875	6.00	0.695	0.0126
37	925	5.68	0.58	0.0048
39	975	5.39	0.492	0.0043
41	1,025	5.12	0.457	
43	1,075	4.89	0.434	
45	1,125	4.67	0.428	
47	1,175	4.47	0.408	
49	1,225	4.28	0.380	
51	1,275	4.12	0.344	
53	1,325	3.97	0.299	
55	1,375	3.82	0.268	
57	1,425	3.69	0.248	
59	1,475	3.56	0.240	
61	1,525	3.45	0.224	
63	1,575	3.33	0.210	
65	1,625	3.23		
67	1,675	3.13		
69	1,725	3.04	0.188	
71	1,775	2.96		
73	1,825	2.87		
75	1,875	2.80		
IT		165,000	16,700	357

Laboratory tests were so favorable that it was decided to make tests in service under actual electrification operating conditions. Co-operation of the Pennsylvania Railroad was sought for the assembly of propulsion and control apparatus furnished by Westinghouse Electric Corporation and the multiple-unit car and its auxiliary apparatus by the Pennsylvania Railroad Company. This assembly has been in trial performances for adjustment and refinement of apparatus for some months. The car is now in revenue service.

In addition to this procedure, the Bell Telephone Laboratories and the American Telephone and Telegraph Company co-operated with Westinghouse and the Pennsylvania Railroad in conducting a series of tests to determine the telephone noise influence aspects of the rectifier car and existing single-phase a-c series motor equipment.

The results of telephone noise influence tests are still in preliminary form and are not described here.

This car was a combination type, half its length being a baggage compartment. All test equipment requiring adjustment and observation, instruments, and oscilloscopes were mounted in this baggage compartment.

The electric equipment consisted of a specially designed transformer, four type *WL-653-B* ignitron tubes for single-phase full-wave rectification, plus a variety of capacitors and reactors as variable test equipment. Two Long Island-type traction motors with control boxes and accelerating grids were used primarily because they could be secured quickly. In the future on an a-c road, voltage tap control from a transformer would be used.

The main circuit schematic for the test car as it was placed in revenue service at the completion of the harmonic tests is shown in Figure 2.

This rectifier car was initially energized on July 15, 1949, since which time it has been under limited operation for apparatus refinement and adjustment with no fundamental difficulties ascertained in approximately 2,500 miles of trial. It was placed in revenue service on October 26, 1949.

SOLUTIONS OF PROBLEMS

Results of the problems mentioned previously are as follows:

Problem 1. Shock and vibration during normal operation has not affected operation in the least. The car has been operated most of the time during the tests pulling a second car as a trailer. It has been operated successfully for sustained periods of time with full-wave rectification from two tubes only; first one pair of tubes were used up to 60 miles per hour for 25 successive accelerations, then the other pair of tubes were used in the same manner. Normally all four tubes would be used. It has been operated intentionally for short periods of time on two tubes with half-wave rectification.

Problem 2. The motors have been operated most of the time with approximately 33 per cent ripple in the direct current. The commutation under these conditions has been black at all times, and the commutators and brushes have an excellent appearance. Limited testing was done with a 5 per cent ripple and a 55 per cent ripple.

The test car was operated for three round trips making all stops between Broad Street Suburban Station, Philadelphia, and Paoli with approximately a 33 per cent ripple in the direct current. The three round trips were repeated the next day with a 5 per cent ripple in the direct current. Both tests resulted in an 86-degree centigrade rise (by thermocouple) in the interpole winding.

Problem 3. The telephone influence of such a rectifier is being investigated on a 25-cycle system. The results, though not complete, include field test data taken on the ignitron-equipped multiple-unit car. It is indicated that practical filters can be produced which will permit the use of rectifiers as a power supply for individual traction units of an electrified railroad system paralleling associated and commercial communication circuits.

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Three-Phase Resistance Measurements

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LARGE DISCREPANCIES between the measured values of resistance of three identical conductors with 3-phase current have been reported by observers.[1] It has been the practice to take the average of the values of resistance measured on the three conductors as being the true value of a-c resistance of each. This procedure is valid if the resistances of three conductors are actually equal.

Unsymmetrical spacing of the three conductors produces unbalanced inductive reactances which in turn produce errors in the measured conductor resistance. These errors can be eliminated by making measurements, first with 3-phase current of one-phase sequence and then with 3-phase current of the opposite phase sequence. The average value of the resistances measured on any one conductor with the two phase sequences is the true value of a-c resistance.

Figure 1 shows a diagram of the measuring circuit which is very similar to that described by Summers.[2] This circuit is an a-c potentiometer. The voltage drop across a standard resistor, shunted by a voltage divider, in the secondary of a current transformer plus the voltage in the secondary of a mutual inductance is made equal to the drop between the potential points on the conductor. The conductors on which these measurements were made are three copper tubes each 30 feet in length with an inner diameter of 0.375 inch and an outer diameter of 0.540 inch. Two potential leads were connected on the outside of each conductor at points 15 feet apart and brought away at right angles to a distance of about 18 feet, then closed to form a rectangular loop. The leads were twisted from this loop to the measuring circuit. In order to minimize the effect of stray fields, two measurements with opposite polarities were made on each conductor for both phase sequences.

With a conductor spacing of approximately 2 inches, $2^1/_4$ inches, and $2^3/_4$ inches, the resistance of *A*-phase conductor measured with positive sequence current was 1.55 milliohms and with negative sequence current 1.30 milliohms giving an average of 1.425 milliohms. The d-c resistance of the same conductor, measured with a Kelvin bridge, was 1.406 ohm. With positive- and negative-phase sequence currents the measured resistances on *B*-phase conductor were 1.08 and 1.28 milliohms respectively, giving an average value of 1.18 milliohms. The d-c resistance of *B*-phase conductor was 1.152 milliohms. The corresponding a-c values for *C*-phase conductor were 1.08 and 1.14 giving an average of 1.11 milliohms compared with a d-c value of 1.087 milliohms. Measurements were repeated for different conductor spacings, and the average values of the individual conductor resistance obtained with opposite phase sequences were substantially the same as those obtained originally. Inductive-reactance measurements were also made, computed from the setting of the mutual inductance *M*, as shown in Figure 1.

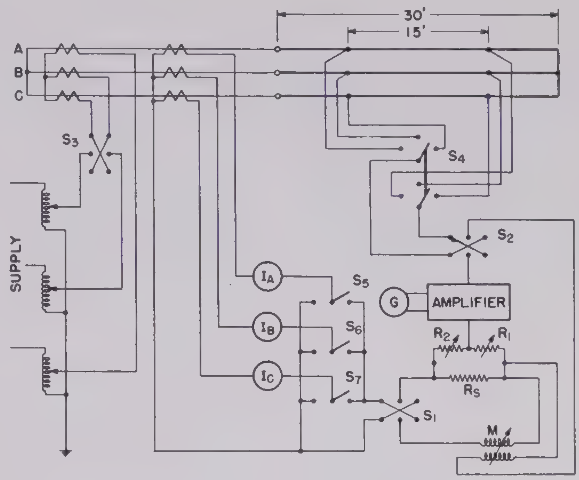

Figure 1. Circuit diagram for 3-phase measurements of resistance and reactance

It can be shown that using only positive-sequence current, the error in the measured value of resistance on *A*-phase conductor (conductor number 1) is $-0.866(Xd_{12}-Xd_{31})$ where Xd_{12} is the separation component of reactance between *A*- and *B*-phase conductors and Xd_{31} is the separation component of reactance between *C*- and *A*-phase conductors.[3] The apparent a-c resistance was computed by adding this term to the d-c resistance. Table I shows a comparison between computed values and measured values of resistance with positive sequence current only.

Table I. Computed Apparent Conductor Resistance for Positive Sequence Current

Phase	$0.866(Xd_{12}-Xd_{31})$	Resistance, milliohms	
		Computed	Measured
A	−0.118	1.53	1.55
B	+0.081	1.07	1.08
C	+0.036	1.12	1.08

Three-phase measurement of resistance followed by one with currents of opposite phase sequence will yield data from which the true value of a-c resistance for each individual conductor can be obtained.

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Digest of paper **50-75,** "Three-Phase Measurements of Resistance," recommended by the AIEE Committee on Instruments and Measurements and approved by the AIEE Technical Program Committee for presentation at the AIEE Winter General Meeting, New York, N. Y., January 30–February 3, 1950. Scheduled for publication in AIEE *Transactions*, volume 69, 1950.

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Automatic Calibration of Oscillator Scales

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THE USE of heterodyne oscillators in testing and maintenance of carrier telephone systems has created the problem of designing long frequency scales of high accuracy and good readability. It has been found that for panel-mounted equipment with a well illuminated scale to be read at arms length the scale modulus should be such that the smallest interval which it is desirable to read is not less than 0.05 inch. For carrier system applications, the corresponding frequency interval is independent of the frequency and so the correct choice is a linear scale.

A scale arrangement of adequate length and yet lending itself to a compact construction consists of a length of moving picture film registering through its perforations against the teeth of a sprocket which in turn is fastened to the worm shaft of the tuning unit. The film carries scale divisions and numbers and in combination with the sprocket forms a direct-reading scale. The loose ends of the film are rolled up on two take-up drums tensioned by springs. A typical scale has a length of 400 inches carrying 2,000 subdivisions and 200 numbers.

The calibration of such a scale and subdivision of the intervals between calibrated points is a slow operation in spite of labor-saving devices. The calibration must be done in a temperature-controlled room to prevent frequency drift and the apparatus must be prewarmed before calibration.

These complications have been removed by the development of a continuous automatic calibration system. In this system an unexposed motion picture film connected to the oscillator to be calibrated is slowly driven past a slit as the oscillator is motor-driven through its frequency range. A subdivided and numbered master scale is also motor-driven and its image is projected on the unexposed film through the slit to generate a scale. By so controlling the speed of the master scale that the setting undergoing projection reads the frequency of the oscillator under test, a true calibration is obtained which after development becomes the oscillator calibration.

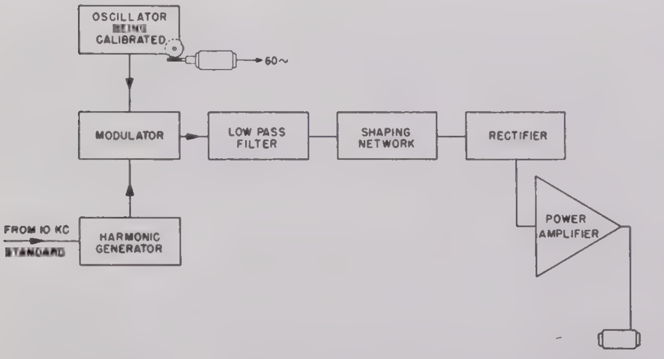

Figure 1. Block schematic of the automatic calibrating system for oscillator scales

An electronic circuit performs the measurement of the instantaneous frequency of the oscillator under test and uses the result of this measurement to control the speed of the motor geared to the master film sprocket. In a current application to a 20-megacycle oscillator the measurement is accomplished by direct comparison at a large number of points with frequencies derived from a primary frequency standard.

A 10-kc frequency standard pulse of less than 0.05-microsecond duration, which has a uniform harmonic frequency spectrum extending beyond 20 megacycles, is led into a modulator together with the output of the oscillator under test, as shown in Figure 1. As the oscillator is driven in the direction of increasing frequency, the output frequency is at some time equal to a harmonic of 10 kc and the beat frequency is zero. Then the beat frequency increases up to 5 kc, beyond which point a filter with a 5-kc cut-off attenuates the output. Above this point the beat frequency between the oscillator and the next higher harmonic is less than 5 kc and, therefore, it appears at the output. It decreases to zero and the cycle repeats itself as the oscillator beats against one harmonic after another up to 20 megacycles.

The variable frequency output of this modulator is next fed to a multiple-frequency discriminator network which has transmission peaks at 1.25 and 3.75 kc and zeros at 0, 2.5, and 5 kc. As the oscillator is being driven over a range of 10 kc the output voltage of the network rises and falls four times at four equal frequency intervals. The output is rectified in the next stage producing a voltage with a frequency of about 30 cycles corresponding to the rate at which the oscillator is driven, which is about 75 kc per second. The 30-cycle signal is amplified and applied to a synchronous motor which, through a gear train, drives a uniformly divided master scale. The gear train is so proportioned that each time the voltage across the synchronous motor goes through four cycles, the master film is advanced 10 kc. Thus the passage of a 10-kc subdivision corresponds to passage of the oscillator frequency through a harmonic of the 10-kc standard. The reproduction of the master scale on the unexposed film is, therefore, a correct calibration. Once the oscillator has been placed in the calibrating position and preliminary adjustments have been made the actual calibration is made in 4.4 minutes. The error of calibration is less than 1 kc from 50 kc to 20 megacycles, and a controlled-temperature room is unnecessary.

Digest of paper **50-80,** "Automatic Calibration of Oscillator Scales," recommended by the AIEE Committee on Instruments and Measurements and approved by the AIEE Technical Program Committee for presentation at the AIEE Winter General Meeting, New York, N. Y., January 30–February 3, 1950. Not scheduled for publication in AIEE *Transactions.*

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A Magnetic Amplifier Frequency Control

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TO SUPPLY power to certain types of shipboard instruments, a source of alternating current is required in which the frequency error must be ±0.1 per cent or less over a range of temperatures, loads, and supply voltages. This need has been met by the use of small motor-driven alternators which run on the ship's d-c power supply. Frequency regulation is accomplished by shunt-field current control in the motor, and the field current is controlled by some form of servomechanism and frequency-sensing device.

In order to overcome the limitations of existing frequency-regulating devices, the magnetic-amplifier-type regulator described herein was developed. This new regulator system has no moving parts, is extremely accurate in performance, and is not affected by shock and vibration. Its schematic diagram is shown in Figure 1.

The frequency control consists of these components:

A. A dynamotor for d-c to a-c conversion.

B. A small permanent-magnet a-c pilot generator attached to the dynamotor shaft.

C and *D.* A pair of series-resonant circuits with rectifiers.

E. A magnetic amplifier, consisting of two toroidal reactors and two self-saturation rectifiers.

F. A control field rectifier.

In operation, two series-resonant circuits *C* and *D* are excited by the output of pilot generator *B* and supply rectified control currents to the magnetic amplifier *E*. The magnetic amplifier controls the current flow to the control field rectifier *F*, which, in turn, supplies rectified current to the control field of the dynamotor. In addition to the principal circuit components, an electric damping circuit is utilized, consisting of capacitor C_1 and two auxiliary windings on the magnetic amplifier reactor cores. The damping circuit is connected in parallel with the control-field winding and produces a magnetomotive force in the magnetic amplifier which is a function of the rate of change of voltage across the rectifier. This additional magnetomotive force acts in a direction to stabilize the frequency of the system.

Temperature stability between 40 and 130 degrees Fahrenheit is obtained by the use of temperature-stabilized Permalloy dust-reactor cores in the two frequency-sensing circuits.

The magnetic amplifier *E* in Figure 1 consists of two ribbon-core toroidal reactors, each of which has four separate windings. The directions of the magnetic fluxes in the reactor cores are as shown by the arrows in the figure. When the dynamotor frequency is exactly 60 cycles, the ampere-turns in the pairs of control windings on each reactor are equal and opposite. When a disturbance in load or supply voltage occurs, the resonant-circuit currents became unbalanced and the reactance of the magnetic amplifier increases or decreases as a function of the net control currents from the sensing circuits. The saturable reactors, in turn, regulate the current to the control field coils of the dynamotor in such a manner as to restore the frequency to the normal value.

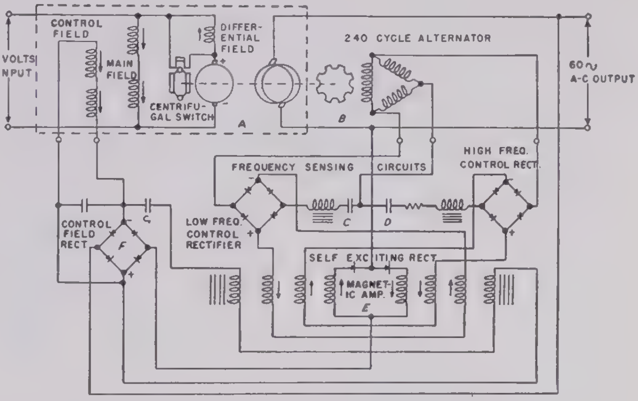

Figure 1. Schematic diagram of a magnefic-amplifier frequency-control unit

Transient response tests on the system indicate that the frequency will return to normal 60-cycle frequency in two-thirds of a second after a load is applied or removed, or following a surge in the supply voltage of as much as ±5.0 per cent. Most of this time delay can be attributed to the inertia of the dynamotor.

To summarize, this magnetic-amplifier frequency control has the following advantages over older devices designed for the same purpose:

1. At normal temperatures the system gives frequency regulation of the order of one part in 5,000 or better without the aid of tuning forks or crystals.
2. The system is stable in operation under fluctuating load, voltage, and operating temperature conditions.
3. There are no moving parts in the system.
4. The regulator is simple in design and inherently free from maintenance troubles, and is not affected by shocks or vibrations normally encountered in use.

This frequency control is an example of the successful application of known magnetic-amplifier theory to a practical problem and is believed to be smaller, lighter, and more effective than other controls designed for the same purpose.

Digest of paper **50-95**, "A Magnetic Amplifier Frequency Control," recommended by the AIEE Committee on Electronics and approved by the AIEE Technical Program Committee for presentation at the AIEE Winter General Meeting, New York, N. Y., January 30–February 3, 1950. Scheduled for publication in AIEE *Transactions*, volume 69, 1950.

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Motor Design for a High-Speed Electrically-Driven Gyroscope

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A GYROSCOPE is a wheel or disk which rotates about an axis through its center (called spin axis) and which is also capable of rotation about one or more axes perpendicular to the spin axis and to each other. If the wheel is mounted so it is capable of rotation about three intersecting axes, it is said to be unconstrained with respect to rotation and possesses then the well-known and interesting property of maintaining the plane of its spin axis fixed in space as long as no external forces are applied to it. This property has been made use of in gyrocompasses, stabilizers, and other instruments which measure or correct any deviation of the supporting body from the reference axis of the gyroscope.

The wheel of the gyroscope, which is called the gyro, can be spun by any convenient means, such as a jet of air, but in most applications it is an integral part of an electric motor, usually the rotor of an induction motor. The gyro motor is quite different from its conventional prototype, however, and this article will attempt to discuss some of the factors which have made these differences necessary. Gyrodynamic theory will be referred to in this article only in so far as it affects the design of the gyro motor itself.

A small motor to be used in a gyroscope must have the highest possible momentum and it must have absolute mass stability. These factors cause many problems not encountered in the design of conventional electric motors. The gyro has a low torque-to-inertia ratio, very high operating speed, and all heat must be conducted from the machine by radiation.

How does an electrically-driven gyro differ from a conventional electric motor? First, and most important, the gyro motor must be designed for the highest possible momentum. Second, its mass stability must be absolute. These requirements are essential to minimize gyroscopic drift and nutation effects, but they also give rise to a number of electrical and mechanical problems which are seldom encountered in the design of ordinary electric motors.

Electrically-driven gyros (see Figure 1) are usually designed as squirrel-cage induction motors, although other types have been used occasionally. For instance, an early model of commercial gyrocompass built after World War I had its gyro designed as a shunt motor so that it could be run directly on the ship's d-c power supply. This seemed a good idea, but it was eventually abandoned because of commutator troubles, even at relatively low speeds. These difficulties would make a real high-speed d-c gyro quite impractical since windage causes so much drag above 10,000 rpm that it is usually necessary to operate all but the smallest aircraft gyros in sealed evacuated cases, and the life expectancy of a commutator operating in a vacuum at high speed would be very short indeed.

For applications in which a rigorously constant-speed gyro is required regardless of voltage variations, synchronous self-starting motors must be used. Hysteresis motors do very well in this work, although they have lower torque and efficiency than do induction motors.

A short discussion on the causes of gyroscopic drift will now be attempted. Any force applied to a freely spinning gyro causes its spin axis to move away from its original position. This motion is called precession and is at right angles to the direction of the applied force. The torque required to maintain a constant velocity of precession is

$$T = I\omega W_p = M_\alpha W_p \tag{1}$$

where I is the moment of inertia of the wheel; ω, its angular velocity; W_p, the velocity of precession; and M_α, the angular momentum.

The velocity of precession is called drift when the torque producing it is caused by gimbal-bearing friction, windage, or other random forces. It can be minimized by operating the gyro in a vacuum, by keeping the ratio of the angular momentum of the wheel to its weight high, and by preventing any axial shift of the wheel while it is in motion. The two latter points are especially important in reducing gimbal-bearing friction, one of the main causes of drift. It would appear, therefore, that the ideal gyro should be designed for a high angular velocity, a large moment of inertia, and the lowest weight possible. In order to compromise these somewhat conflicting requirements, the usual procedure is to turn the conventional induction motor inside-out; that is to have the squirrel cage revolve outside the stator instead of inside it. This results in a considerable increase of inertia without adding very much to the weight of the rotor. The angular velocity then can be made as high as desired by increasing the frequency of the power supply. However, since the squirrel-cage laminations do not have much tensile strength, it is necessary to press them into a rim made of a high-strength material. This permits the squirrel cage to rotate safely at the high peripheral speeds for which the rim is designed. It should be pointed out, however, that bearing life is the real limit on speed, rather than the strength of the rim. A wheel 4.5 inches in diameter with a rim made of *SAE 4340* steel,

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for instance, can, as far as the rim itself is concerned, be spun safely at 75,000 rpm, but because of the high temperatures developed in the bearings at these speeds and the present limitations on lubrication techniques the bearing life would be rather short.

Other basic design criteria are positive starting torque under adverse conditions, such as extreme cold and reduced voltage, reasonable run-up time for the gyro to reach its normal operating speed, low slip, and low operating temperature. This last condition is most important, since high-speed gyros are usually run in a vacuum to minimize windage, and heat dissipation then becomes a real problem.

Techniques used to overcome these difficulties will be described later.

A brief discussion of the power supply may be of interest at this point. Since the overwhelming majority of gyros are squirrel-cage induction motors, their synchronous speed is entirely governed by the frequency of the supply and number of poles in the stator winding. The standard industrial frequency of 60 cycles per second is too low to provide a high momentum-to-weight ratio, so an independent power supply, usually a motor-driven alternator, is required. In special cases, where stable frequency is imperative, electronic power supplies controlled by an accurate tuning fork or a crystal oscillator are the best solution.

ELECTRICAL DESIGN

An electrically-driven gyro is essentially a no-load induction motor, and it is designed in general by the same well-known procedures and equations that are used for conventional induction motors. There are, however, a few notable differences. The regular industrial polyphase induction motor is a high-torque and comparatively low-speed machine, fan-cooled, and with a moderate torque-to-inertia ratio of the rotor. The gyro, on the other hand, has an extremely low torque-to-inertia ratio, a very high operating speed, and with vacuum-sealed construction radiation must be depended upon almost entirely for cooling.

Stator. A good sinusoidal flux distribution, free of winding and tooth harmonics, is important in any induction motor, and doubly so in a gyro. These harmonics produce unexpected reduction in torque at certain critical speeds, sometimes of such severity that the motor may never get up to speed at all. The situation is especially serious in the case of gyros because of their extremely low torque-to-inertia ratios. For example, the torque-to-inertia ratio of a conventional 1/4-horsepower 60-cycle induction motor is 540 radians per second squared, while that of a typical modern high-speed gyro is only about five radians per second squared. (It may be of interest to compare these ratios with that of small low-inertia servomotors which are at the other end of the scale, and sometimes exceed 30,000 radians per second squared.) In addition to their low torque and high inertia, modern gyro rotors are operated at very high speeds, usually at 24,000 rpm or even higher, which makes it all the more important to maintain a very steady torque during the long run-up period.

Studies by Kron,[1] Trickey,[2] and others have shown that irregularities in the torque-speed curve of induction motors are caused by certain harmonics of the revolving magnetomotive-force wave and that these harmonics are partly the result of improper winding distribution and partly of certain combinations of rotor and stator slots. In addition, either the slots of the stator or the slots of the rotor must be skewed to prevent irregular, jerky motion at low speeds.

These considerations, therefore, require that the stator laminations have a large number of slots and that the winding be carefully designed and proportioned according to the sine law. This type of winding, called concentric, is familiar to all fractional-horsepower motor designers and gives a stepped magnetomotive-force wave which is reasonably close to the impressed sinusoidal voltage. For the present design, an 18-slot lamination was chosen; the slot number is divisible by the poles (two) and the phases (three).

A 36-slot lamination would give a better magnetomotive-force wave shape but would be difficult to wind because of the small size of the slots, while a 24-slot lamination would tend to lock in with the 25-bar rotor. It would, of course, be possible to increase the number of rotor bars above 25, but the bars would then become thin and

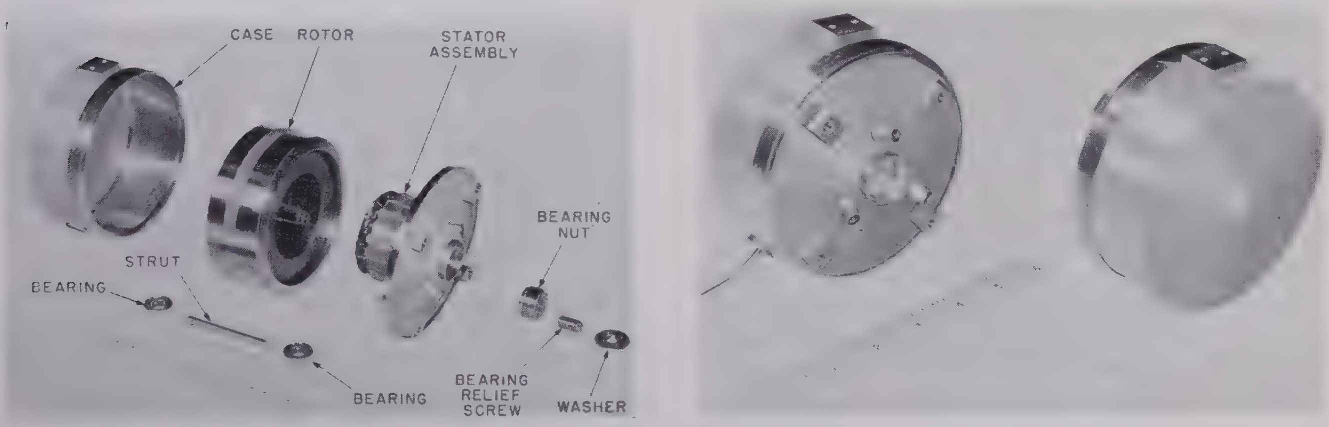


Figure 1. **(A, left) Exploded view of gyro components and (B, right) front and back views of gyro assembled in its case**

difficult to cast, so the first combination was chosen as the best practical compromise.

Flux densities should be kept low (under 60,000 lines per square inch, if possible, for high silicon steel) since high densities contribute to an increase of magnetizing current. For the same reason, the air gap is made small, 0.010 inch or less. It should be noted, in this connection, that small air gaps intensify the harmonic effects that have been discussed previously, which is one more reason for insisting on sinusoidal flux distribution. A subassembly of a typical stator is shown in Figure 2.

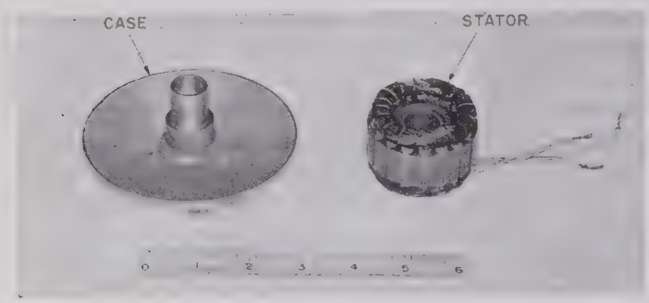


Figure 2. Subassembly of a typical stator and case

Rotor. The rotor, or squirrel cage, differs in several points from that of the ordinary induction motor. To begin with, as mentioned earlier, it rotates outside the stator, although this is a mechanical rather than an electrical consideration. In addition, the peculiar operating conditions of the gyro, which have been enumerated previously, make it necessary to use a somewhat unusual type of lamination design.

In conventional fractional-horsepower motors, the squirrel cage bars are usually either round or perhaps slightly elongated, and the slot which surrounds each bar is open toward the stator. In the gyro squirrel cage, the bars are deep and narrow in cross section, and the slots are closed or bridged instead of open (see Figure 3). The reason for this construction follows.

In round or square bars, the current distribution in the bars is practically uniform, whether the motor is starting up or running. This means that the effective resistance of the squirrel cage is the same under both conditions. If the bars are deep and narrow, however, the current distribution is different when the motor is starting than when it is running. When the rotor is stalled, with full line voltage applied to the stator, heavy eddy currents are induced in the bars, and the normal bar current is crowded into the head of the bar which is nearest the air gap.

This is equivalent to reducing the area of each bar, or, in other words, increasing its resistance. When the rotor has reached full operating speed, the eddy currents virtually disappear, and the normal current distribution in the bars becomes uniform. Therefore, the effective resistance of the bars is reduced. This construction produces a rotor with high starting and low running resistance, and since the starting torque is directly and the slip inversely proportional to the rotor resistance, a high-starting-torque low-slip motor is obtained at no additional increase in power consumption.

The starting current of a gyro, even with a deep-bar squirrel cage, is quite heavy if it is started across the line at full voltage. The copper losses will, therefore, be dangerously high during the run-up period since it would be impractical to wind the stator with wire large enough to carry safely the starting current which is normally 20 times higher than the running current. And since the run-up time of a high-speed rotor is quite appreciable, the stator winding will overheat severely unless special precautions are taken to reduce the starting current. The only way of accomplishing this other than by the use of starting boxes or variable frequency power supplies is to increase the leakage reactance of the squirrel cage. A typical slot leakage reactance equation is

$$X_s = 2\pi f C^2 C_W{}^2 \left[\frac{6.38\, l}{S_s}\right]\left[F_{ss} + \frac{S_s}{S_r} F_{sr}\right] 10^{-8} \text{ ohms} \tag{2}$$

where

f = frequency in cycles per second
C = conductors in series per phase
C_W = winding constant
l = length of stacking
S_s = stator slots
S_r = rotor slots
F_{ss} = stator slot leakage factor
F_{sr} = rotor slot leakage factor

It can be seen from this equation that if the rotor slot reactance factor F_{sr} is made large, the slot leakage reactance will increase proportionally. This factor F_{sr} is computed from the dimensions of the slot and from slot reactance factor curves that can be found in standard design handbooks. By closing or bridging the slot, the value of F_{sr} can be greatly increased and the locked impedance of the gyro can be made high enough to keep the starting current at a safe value.

Bridged slots are very seldom used in ordinary induction motors since the run-up time at the usual commercial fre-

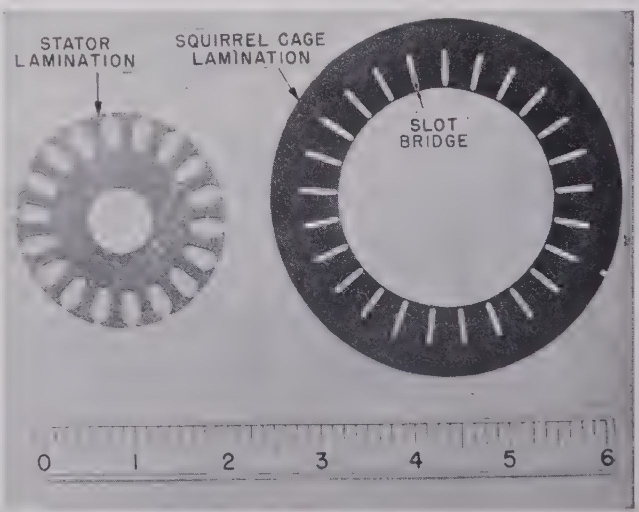


Figure 3. Stator and squirrel-cage laminations showing the narrow, deep bars of the squirrel cage with closed slots

quencies is practically instantaneous, and the inrush current is almost immediately limited by the counter electromotive force.

MECHANICAL DESIGN

Four points are particularly important in the mechanical design of a high-speed gyro:

1. Wheel stresses.
2. Preloading of bearings and mass stability.
3. Bearing lubrication.
4. Internal case pressure.

Wheel Stresses. The rim which surrounds the squirrel-cage stack (see Figure 4) must be designed to withstand safely the peripheral speed that the gyro will attain. For speeds above 24,000 rpm and for wheels between four and five inches in diameter, *SAE 4140* (chrome molybdenum) or *SAE 4340* (nickel molybdenum) have been used, both of which have sufficient yield strength for the job. The latter is to be preferred because it forges more easily than *4140.* The maximum safe speed of the wheel can be computed from Timoshenko's stress equation for rotating thick rings

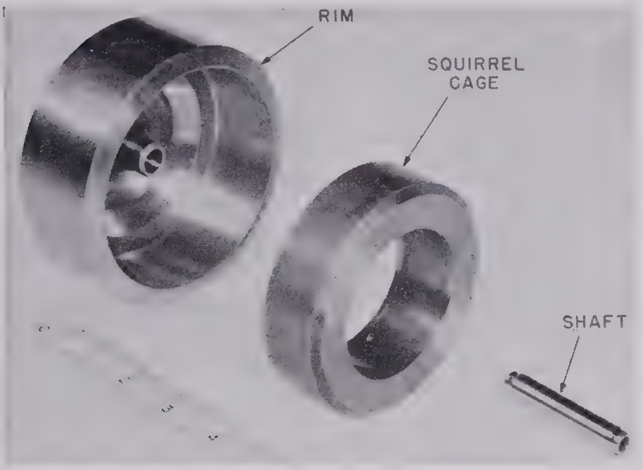


Figure 4. Rim, squirrel cage, and shaft designed to withstand safely the high peripheral speed attained by the gyro

$$\sigma_{\max}=\frac{\gamma v^2}{g}\,\frac{3+\mu}{4}\left(1+\frac{1-\mu}{3+\mu}\propto^2\right) \tag{3}$$

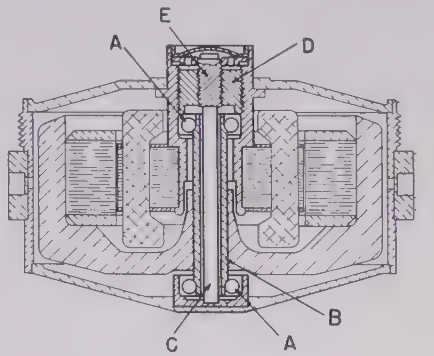
where

σ = maximum stress in pounds per square inch at inner rim of wheel
γ = unit weight of wheel in pounds per cubic inch
g = acceleration of gravity inches per second squared
v = peripheral speed of wheel in inches per second
μ = Poisson's ratio
$\propto = \dfrac{\text{inner radius}}{\text{outer radius}}$

Using *SAE 4340* which has a yield strength of 225,000 pounds per square inch, the ultimate speed at which the wheel could be driven is 75,000 rpm.

Preloading of Bearings and Mass Stability. A heavy flywheel revolving at very high speed requires the best of precision ball bearings, perfectly aligned, with good lubrication, and with absolutely no end shake. As was explained earlier, end shake cannot be tolerated in a gyro because any displacement of the rotor along its spin axis will produce an unbalanced weight shift on the gimbal bearings which in turn will apply a precessing torque to the gyro and cause it to drift. End shake is usually eliminated by spring loading the bearings axially, but this method has the serious disadvantage of increasing the friction and the temperature of the bearings.

Figure 5. Section view of the assembled gyro showing details of the bearing mounting



The ideal combination, therefore, is a perfectly free bearing with no end shake; this was attained in the following manner (see Figure 5). The inner races of the bearings *AA* are mounted on a hollow shaft *B* surrounding a compression strut *C.* The bearings first are clamped down tight by a nut *D*, and then the relief screw is forced against the strut until all the pressure on the inner race is removed entirely, while the outer race remains tightly clamped as before.

The procedure described applies, of course, to bearings with a fixed outer race and a rotating inner race. This is the system that is most often used on gyros because the linear speed of the inner race is slower than that of the outer race and the bearing can be lubricated and adjusted more easily. In some cases, however, special problems arise which make it mandatory to use the outer race as the rotating member of the bearing, but this construction should be avoided if possible.

Bearing Lubrication. Bearings can be lubricated by wicks or by grease. Because of the large amount of oil that can be stored and fed to the bearings by wicks, this type of lubrication appears attractive for gyros that are required to operate continuously for very long periods of time, although there are serious disadvantages attached to it. For one thing, it is difficult to regulate the flow of oil through the wicks, and too much oil, even though it will insure a cool bearing, will also cause an appreciable amount of drag by viscous friction.

In addition, even high-boiling-point oils give off vapor when brought into contact with warm surfaces such as the inside of the gyro case, and oil vapor is a powerful contributor to windage drag on the wheel because of its viscosity.

Grease, on the other hand, produces practically no vapor and is highly resistant to heat. It will not lubricate a bearing indefinitely, as will a steady stream of oil, but it remains effective for a very long time, nevertheless. Gyros have been operated at standard frequencies for several thousand hours with grease-filled bearings without visible harm to the latter.

Internal Case Pressure. It has been explained earlier that windage should be kept as low as possible for the efficient operation of high-speed gyros. Even small amounts of entrapped air or vapor produce an appreciable drag on the rotor which shows up as excessive power consumption and overheating. Therefore, it is customary to operate the gyro in a case which has been evacuated and sealed off. The case is first pumped down to about 100 microns (0.1 millimeter), but after a few hours of operation the pressure usually rises to one millimeter because of gases released from the impregnating compound of the winding and also from oil vapor. Another technique that is frequently used is to evacuate the case as before, but before sealing it off, to introduce a small amount of helium (25 to 50 millimeters). This very light gas is also a good heat conductor, and although the drag on the wheel and the power consumption are somewhat increased, the gyro actually runs cooler. In addition to entrapped air or oil vapor, one of the worst offenders in producing case pressure is the laminating and impregnating compound of the stator winding. In spite of prolonged baking, it is almost impossible to remove completely all volatile products in the impregnation, and these gases will in time build up an appreciable pressure in the gyro case. The best way of overcoming this is to run the gyro for several hours with the case connected to a vacuum pump that is operating continuously. This gives good results, but it is slow and expensive.

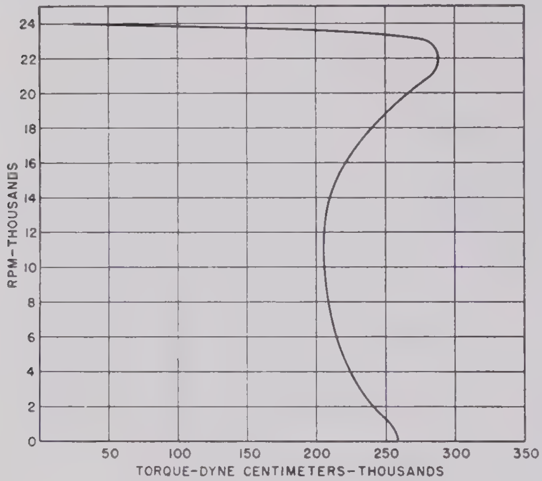


Figure 6. Typical torque-speed curve of a gyro rotor showing the flat top of the low-resistance squirrel cage with the high starting torque resulting from the deep bar construction

The starting and operating characteristics of a gyro are evaluated from its torque-speed curves, just as in the case of any other induction motor. However, since it is impractical to measure the torque directly with a dynamometer, it is necessary to compute it from the acceleration and deceleration curves of the gyro. The angular velocity of the rotor can be measured optically with a stroboscope, if the construction of the gyro is such that the rotor can be spun outside of its case in a bell jar. Where this is not possible, the fundamental frequency of the rotor may be picked up acoustically by a microphone attached to the case, and compared with a variable frequency in a cathode-ray oscilloscope.

The total mechanical torque developed by the rotor at any instant is given by the following expression:

$$T = I\alpha \tag{4}$$

where I, the moment of inertia of the rotor, is in gravity units and α, the acceleration, in radians per second squared. If there were no friction or windage present, the slope of the acceleration curve multiplied by the inertia of the rotor would yield the total torque developed by the rotor at any instant. Friction and windage torques reduce the slope of the acceleration curve, however, so it is necessary to add them (as given by the deceleration curve) to the acceleration torque to obtain the true total mechanical torque developed by the rotor. Centimeter-gram-second units are commonly used in these computations, and the torque is obtained in dyne-centimeters. A typical torque-speed curve is shown in Figure 6. The flat top of this curve is characteristic of induction motors with low-resistance squirrel cages while the high starting torque resulting from the deep-bar construction is clearly visible.

Stator winding temperatures should be checked frequently by the resistance method during the initial run-up tests. Although this only gives the average temperature of the winding at any instant, it is sufficiently accurate to detect any dangerous increase in stator temperature.

Case pressure can be measured by a thermocouple pressure gauge or a McLeod gauge, although the latter may give erroneous readings if any condensable vapors are present, since the McLeod will only read pure gas pressure. For relatively high pressures, as when the gyro is operated in helium, a manometer is usually sufficient.

CONCLUSIONS

The design procedures that have been described in this article were developed to meet the requirements of a moderately heavy but high-speed gyro for which they proved quite effective. The future trend in gyro development is undoubtedly directed toward increasingly high angular speeds, and refinements in the techniques described here will probably provide an adequate solution. Maintaining a low case pressure and more efficient bearing lubrication and cooling are perhaps the two items that most urgently require improvement.

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Losses in Power Transmission Networks

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THE DETERMINATION of transmission-system losses as a function of generating-station loading is of importance to the engineers responsible for the efficient operation of electric power systems. Those responsible for load dispatching have for the most part operated with a good knowledge of generation costs in each individual station, but have had relatively little knowledge of the effect on system losses resulting from shift of load from one station to another. In order to operate at a maximum over-all efficiency it is necessary to determine, for any generator schedule, the cost of system losses and then to correlate these costs with station operating costs. Such an approach is of value in the operation of existing stations and in the location of proposed new generating stations. The present article is concerned with the derivation of a loss formula, expressing the total transmission loss in terms of station loadings. The formula may be applied to the co-ordination of losses with station costs as described in a recent paper.[1]

Power system losses are commonly obtained from network-analyzer studies in which I^2R losses are calculated for each line, the method being repeated for each anticipated load schedule. A mathematical formula for transmission system losses would offer certain advantages over analyzer data as follows:

1. Losses associated with operating conditions not previously anticipated may be readily determined without further testing.
2. The loss formula, combined mathematically with incremental fuel costs, provides a single expression for total-system generation costs which may be minimized by the methods of calculus.
3. From the system loss formula may be derived a simple relation which gives the incremental loss incurred in transferring a block of power from one source to another. This is of particular interest when the two sources considered are two interconnection points, and the power considered is "hauled power."

Any system-loss formula to be of practical significance must be subject to certain simplifying assumptions. The basic approximations involved are

1. For a given total load, each individual substation load is represented as a certain current which has a constant magnitude and fixed relative-angular position with respect to other load currents, regardless of the manner in which the total generation is distributed among the sources.
2. As the total system load varies, the magnitude of each individual load current varies proportionately and maintains its fixed relative-angular position with respect to other load currents. Suitable values of load currents may be obtained from a selected typical intermediate-power-flow condition which is taken as the normal or reference condition.

A loss formula developed for the 4-source system of Figure 1 is of the form

$$P_L=0.306P_1^2+0.667P_2^2+0.229P_3^2+0.362P_4^2 -0.210P_1P_2+0.276P_1P_3-0.012P_1P_4-0.220P_2P_3 +0.332P_2P_4-0.072P_3P_4$$

where P_L is in kilowatts.

The constants of the loss formula are determined from a network-analyzer study of a selected average load condition combined with certain analyzer measurements to determine current distribution throughout the network.

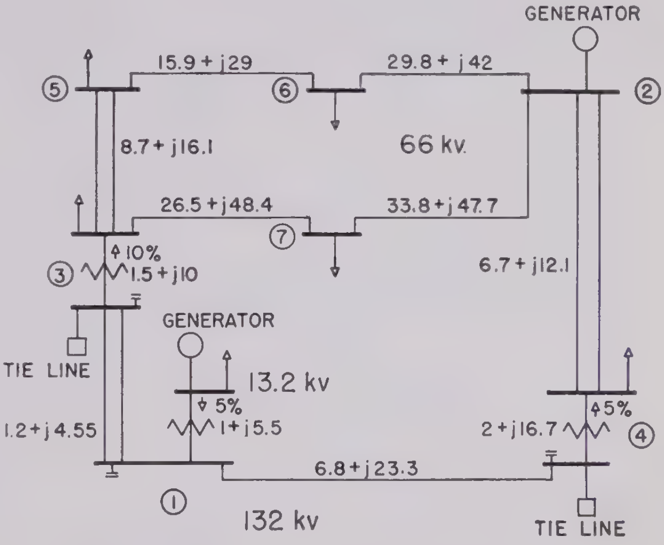

Figure 1. Sample system; impedances are given in per cent on a 100-megavolt-ampere base

As a check on the accuracy of the loss formula for the system of Figure 1, readings were taken on the network analyzer for several loading conditions to permit calculation of the total losses line by line. For these several conditions, values of total loss as given by the formula were compared with the losses as obtained by direct computation. Deviations were found to be small and indicate the reliability of the formula. The incremental loss associated with the through transfer of p megawatts from interconnection *3* to interconnection *4* is given by the equation

$$\Delta P_L=0.66p^2+14.9p$$

This relation applies for one particular set of loading conditions on generators *1* and *2*. Other equations of this form may be developed for other load schedules from the total loss formula.

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A Voltage Gradient Meter

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EARLY IN the studies now in progress on the Tidd 500-kv test lines at Brilliant, Ohio, it was thought that the voltage gradient at the earth's surface might have an important effect on corona and radio influence. Since the phase conductors on a grounded-neutral transmission system are grounded for d-c potentials through the transformers, the earth's electric gradient induces a static charge on these conductors of such polarity and magnitude as to nullify exactly the potential which would exist in space if the conductors were not present. The presence of this induced static charge establishes a gradient on the surface of the conductors which theoretically is superimposed upon the gradient produced by the applied alternating voltage, and thus it may alter the corona and radio influence performance of the line. It was decided to include an investigation of these effects in the Tidd test program.

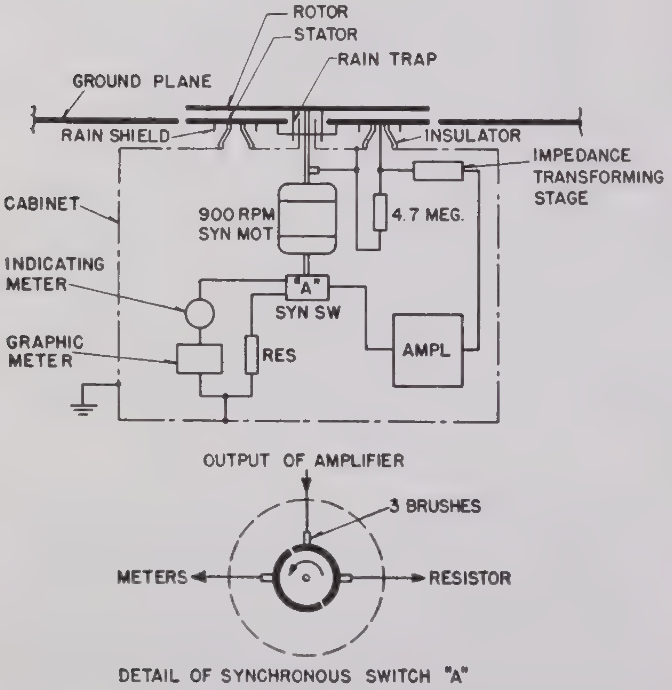

Figure 1. Schematic diagram of electric voltage gradient meter

A gradient meter suitable for use on the Tidd project was not available, so it was necessary to undertake the design and construction of a suitable instrument. The resulting device has a number of features which have not been available on previous instruments and it is ideally suited for this application. It is thought that a description of this instrument will be of value to other investigators.

This instrument is an example of the so-called "generator"-type voltage gradient meter. Figure 1 shows a schematic view of the instrument. The exposed components of the instrument are the detector plates (stators) mounted in the center of the ground plane, and the rotor, which alternately shields and exposes the stator to the earth's electric field. An amplifier, a motor, a synchronous switch, and a recorder are mounted inside a steel cabinet.

When the stator is covered, there is no voltage gradient at its upper surface and hence its charge is zero. When the stator is uncovered, it is exposed to the earth's electric field and a current flows through the ground connection of such magnitude that the charge distribution in the stator is that which is dictated by the voltage gradient at its surface. This current is much too small to be measured directly, so the stator is actually grounded through a 4.7-megohm resistor, and the voltage appearing across this resistor is fed into a special amplifier.

In this type of gradient meter, it is necessary to use special means to determine the polarity of the electric field. A synchronous switch is used for this purpose. This switch connects the output of the amplifier to the recording meter when the stator is being shielded by the rotor, and to ground through a resistor during the exposing period.

A special requirement of this instrument is that it be insensitive to comparatively strong a-c fields. This is accomplished by turning the rotor at a synchronous speed of 900 rpm so that each incremental area of the stator is exposed to the a-c field for one full cycle and then covered for a cycle, and the net effect is zero.

The stator is mounted so that it is part of an extensive ground plane. The field on its upper surface is the same as the voltage gradient at the surface of the earth. The instrument was calibrated by placing an artificial cloud over the ground plane and applying known direct voltages to the artificial cloud.

Four scale ranges are available giving full scale deflections at 40,000, 4,000, 400, and 40 volts per meter. A unique feature is that the lower third of the scale is approximately linear to permit accurate readings of fields of low magnitude, and the upper two-thirds of the scale are compressed in an approximately logarithmic manner enabling measurement of comparatively high voltage gradients without a change of scale setting. This is an important feature as the instrument is left unattended for continuous recording over long periods. An automatic gain-control circuit with a delay voltage is used to provide this type of scale.

The amplifier has been made insensitive to voltage fluctuations and tube changes by the use of voltage-regulating tubes and inverse feedback.

Digest of paper 50-98, "A Voltage Gradient Meter," recommended by the AIEE Committees on Instruments and Measurements and Transmission and Distribution and approved by the AIEE Technical Program Committee for presentation at the AIEE Winter General Meeting, New York, N. Y., January 30–February 3, 1950. Scheduled for publication in AIEE *Transactions*, volume 69, 1950.

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Lightning Arrester Protective Levels and Transformer Insulation

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This article presents the results of impulse tests using lightning arresters with transformers. It indicates the high degree of protection obtained for the transformers by the use of such lightning arresters and suggests changes which may be made in basic insulation levels by reference to such tests.

CURVES showing the relations between lightning arrester discharge voltages and transformer impulse strengths are often published to show the margin between the two and to illustrate how securely protection is obtained. As published, they always show a considerable margin. Furthermore, as published, they reflect the values which have been set up as commercial standards.

Some engineers, particularly transformer engineers, are interested in the conditions possible in service to see if the apparatus they design is adequate for service. Some operators are interested too, since they buy both lightning arresters and transformers, and the establishment of basic insulation levels depends on these relations.

Impulse tests have been made by transformer engineers for this purpose in the past, using lightning arresters and transformers, but the results were never published. One such test which does not conform to the usual impression of the relations between arresters and transformers is reported here, but it does indicate that a high degree of protection is obtained.

The standards of lightning arrester performance have been presented recently.[1] They are extremely valuable in standardizing the method by which arresters can be tested to determine compliance with commercial standards and to give an idea as to the limiting voltages under these conditions.

Using such data, curves showing the degree of protection to apparatus can be drawn. The curves shown in Figure 1 are illustrative of the relations usually given to show the minimum values of transformer insulation and the average arrester performance. However, there are some other considerations to be taken care of to obtain the real picture. One of these is the fact that the arrester performance is average and may exceed the values shown by 10 or 15 per cent. Actually, it is very likely that this is a pessimistic viewpoint, but there are some matters which make conditions worse. Such conditions are separation of the arrester from the apparatus and the possibility of high rates of current discharge or high rates of rise of such discharges. One method of allowing for them has been a fixed percentage, or a fixed quantity, or both. However, little experimental data showing the correspondence of this allowance and possible actual field conditions have been presented. Experience that the use of the allowance has given good service has been given as justification.

The transformer standards establish minimum values of transformer insulation. These values are exceeded for two reasons. First, there must be some margin allowed for testing insulation. For example, if a chopped wave of 230 kv is required, the tester calibrates the surge generator

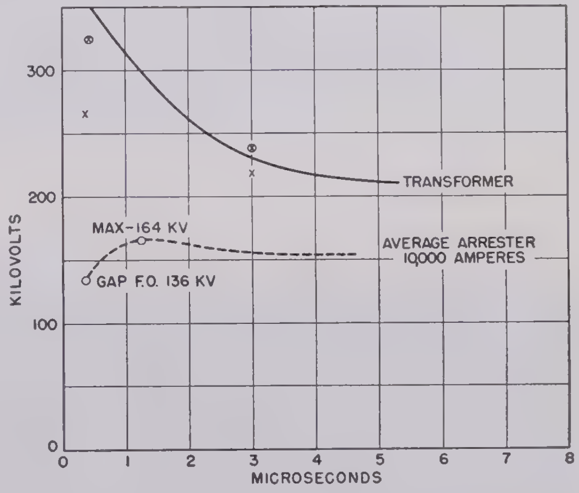

Figure 1. Relations between lightning arrester performance and test data. Average data for a 37-kv line-type lightning arrester is shown on the dashed line. The curve is estimated but is assumed for a 10/20 lightning-arrester discharge current wave to give a 1.5/40 voltage wave. The solid line represents minimum values for transformers demonstrated by test

Crosses represent voltages at the lightning arrester and transformer, with both as near together as possible. The crest of the wave was at less than one-half microsecond, and the average value was over 220 kv for the equivalent of at least three microseconds (Figure 3B). It is recognized that these do not form points on a time lag curve but show comparative strengths only. Circled crosses represent the lightning arrester and transformer voltages with 50-foot separation. The 326 kv at the transformer had very short duration and is shown less than one-half microsecond (Figure 3E). The lightning arrester voltage is shown as 235 kv for the equivalent of three microseconds (Figure 3F). This comparison shows how the separation between the lightning arrester and transformer, leading to high-frequency oscillations, requires steep wave front strength in the transformer

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Full text of paper **50-17**, "Margins Between Arrester Protective Levels and Transformer Insulation," recommended by the AIEE Committee on Transformers and approved by the AIEE Technical Program Committee for presentation at the AIEE Winter General Meeting, New York, N. Y., January 30–February 3, 1950. Scheduled for publication in AIEE *Transactions*, volume 69, 1950.

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The data presented in this paper were obtained during the development of a possible new line of transformers at the Pittsburgh works of the Allis-Chalmers Manufacturing Company.

at some lower voltage and determines the charging voltage for 230 kv by extrapolation. Depending on a number of variables, the actual voltage and specified time may be exceeded by 10 to 15 kv or one or more microseconds. Second, the designer will attempt to provide a margin to prevent failures on test and damage. On the other hand, the conditions used for test on the lightning arresters are not as severe as they might be, since a 10/20 current wave is the basis of test. This means it takes ten microseconds for the current wave to reach its crest and 20 microseconds for the tail of the wave to decrease to one-half the value of the crest. Hence, the commercial tests do not put the transformer in a particularly favorable light, and on the contrary, they put the lightning arrester in a favorable one. A more logical method of procedure would be to use minimum strengths for the transformers, as is now done, and maximum (not average) limiting voltages for lightning arresters should be at least one of the test or guarantee values. Perhaps also they should include the most severe current condition which is to be expected in service.

In order to illustrate this point of view, some tests were made recently on some 34.5-kv transformer coils and insulation, both with and without lightning arresters. The object was to illustrate the effect of steep rates of current rise and separation of the arrester from the transformer. The tests are not beyond question so far as some technicalities are concerned, but they certainly are illustrative of possible field conditions.

The coils and insulation used were typical for 34.5-kv class, which should stand the following tests: full wave, 200 kv; chopped wave, 230 kv; steep-front wave, 345 kv in 0.5 microsecond.

The transformer coils and bushing were set up with a 9-inch rod gap as near as possible. The surge generator was adjusted to give a rate of voltage rise of about 1,500 kv per microsecond. The result of the test is shown on oscillogram *A*, Figure 2. The voltage was 513 kv, reached in about 0.33 microsecond.

Next, a 37-kv lightning arrester, of good manufacture and rated as a line-type lightning arrester, was set up as close as possible to the transformer model. It will be noted that the voltage is greatly reduced, as shown in oscillogram *B*, Figure 2, to be a relatively long wave but to be only 176 kv.

Further tests were made with the arrester between the transformer and generator. The generator setting was unchanged. On one such test, the voltage at the lightning arrester is shown on oscillogram *C*, Figure 2, and was 176 kv. The voltage at the transformer was shown on oscillogram *D*, Figure 2. The peak was 214 kv. The distance between the lightning arrester and the transformer was 50 feet of line. It would seem that this might be a possible condition in the field. However, although the voltage at the transformer was 214 kv, it existed for a small fraction of a microsecond.

Since voltage rises of lightning of 1,000 kv per microsecond have been cited, this might be considered to prove that, at least so far as ordinary rates of voltage rise are concerned, the lightning arrester has done a very good job in preventing flashover and limiting the voltage on the apparatus. In these tests about 500 ohms of resistance were in series within the generator.

Another series of tests were made without internal resistance in the generator. The model and 9-inch rod gap were close together. Oscillogram *A*, Figure 3, shows a flashover on the front of the wave of 556 kv, reached in one-fourth microsecond, giving a rate of rise of over 2,200 kv per microsecond. With the arrester immediately adjacent, the maximum voltage was 262 kv, and the average of the curve was 220 kv. It decreased rapidly in a microsecond or so. This is shown on oscillogram *B*, Figure 3.

Similar tests were made with various separations between the lightning arrester and transformer. One such test was made with a 25-foot separation. In that case the voltage at the lightning arrester was

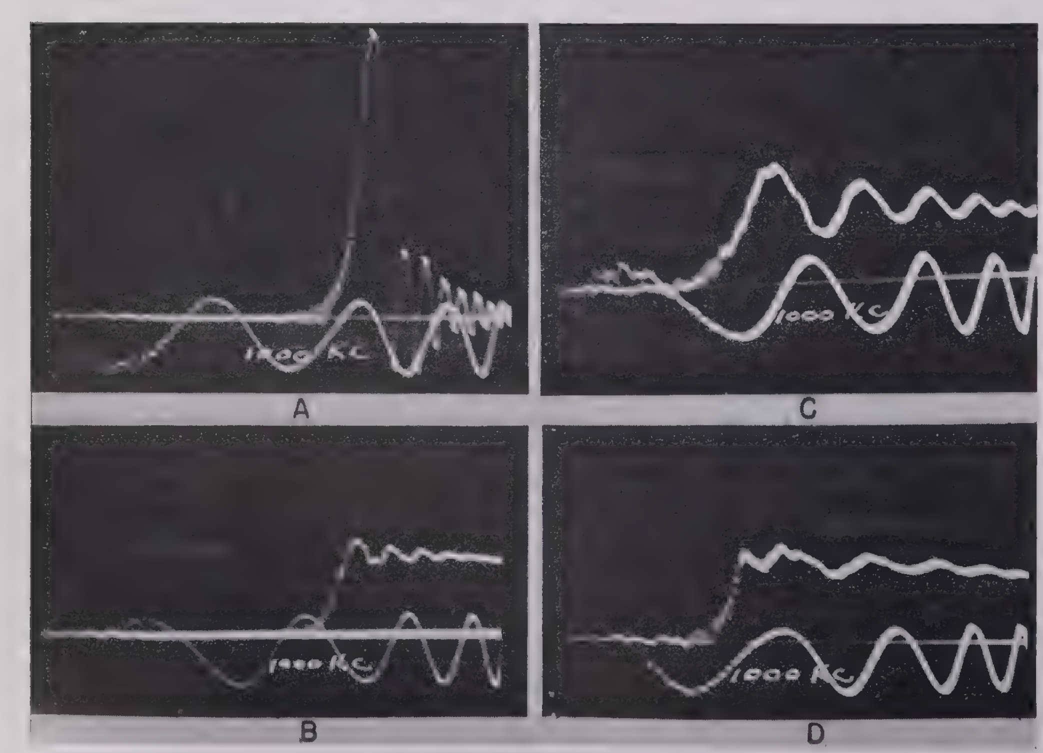

Figure 2. Oscillograms with 1,500-kv-per-microsecond wave

A—Nine-inch rod gap flashover in front of wave
B—Lightning arrester voltage, same surge generator setting as A
C—Transformer voltage 50 feet from lightning arrester
D—Lightning arrester voltage corresponding to C

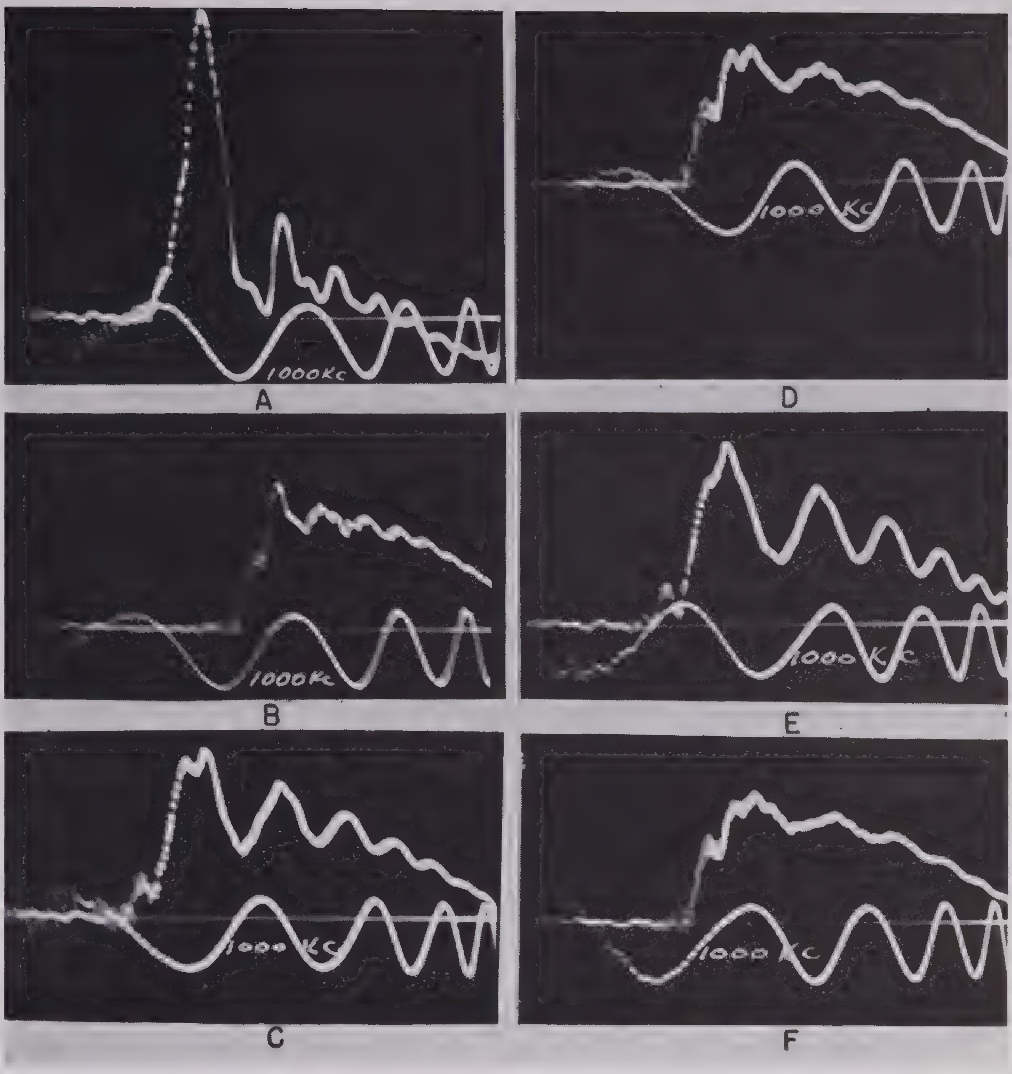

Figure 3. Oscillograms with 2,200-kv-per-microsecond wave

A—Nine-inch rod gap flashover in front of wave
B—Lightning arrester voltage
C—Transformer voltage 25 feet from lightning arrester
D—Lightning arrester voltage corresponding to C
E—Transformer voltage 50 feet from lightning arrester
F—Lightning arrester voltage corresponding to E

246 kv and is shown on oscillogram *D*, Figure 3. The voltage at the transformer was 310 kv and is shown on oscillogram *C*, Figure 3. It is easy to see that the duration of this voltage is only a fraction of a microsecond.

Results with a 50-foot separation are shown on oscillograms *E* and *F*, Figure 3, where voltages at the transformer and arrester are shown in their respective order. The highest voltages were 235 and 326 kv respectively. The 9-inch gap was in parallel with the transformer for all tests. There were no gap flashovers during the tests described. After these tests and many even more severe, investigation showed that no damage was done to the transformer insulation. No measurements of discharge currents were taken, in order to simplify the test procedure. Such measurements would be desirable by those interested primarily in lightning arrester performance.

TEST RESULTS

Although these tests make no pretense of being a complete study of the subject, it is believed that they do permit drawing some conclusions.

For example, the conditions illustrated here, even in the worst case, are probably not as severe as they could be in service. Under these conditions, protection was actually obtained both to service and the apparatus with the lightning arrester. Protection to the apparatus only was obtained with gaps. Perhaps the limits of assumed lightning severity should be further explored since no general agreement as to lightning arrester current limits for given voltage classes and applications has been reached. Since the effect of separation of the lightning arrester and apparatus results in short steep-front oscillations, it would seem that steep-front strength in transformers is desirable. Unless conditions much worse than in these tests exist, normal transformer levels would seem to be sufficient. In other words, high-voltage oscillations due to reflections need not be feared greatly if steep-front strength is built into the apparatus.

The relatively longer steady voltage durations, with high arrester currents, and with the lightning arrester at the transformer, seem to be close to or exceed the present transformer levels. Actually, they did not exceed the strength as actually built in, even in the worst case. If the transformer barely had the American Standards Association level of full-wave strength, more failures might result in service. The usual relations shown for arresters and transformers do not seem entirely correct. They are indicated on Figure 1.

The relations given here apply to the lower voltage classes. Conditions might be much different for higher voltage classes. Tests under these conditions have been made before, and it might be well if more comprehensive tests were made and reported. Due to overhead ground protection, surge currents are often small, and if so, transformer insulation might even be reduced.

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Electrical Essays

Force on a Dielectric, or Physicists Are Just as Confusing

I had to go back to the Research Laboratory for some tools which I had left there the time I did that repair job on the Van de Graaff Atom Smasher. I found two physicists there, running the machine. "Here's a chance to get some expert opinion on my Electrostatic Space Ship (*EE, Feb '50, p 164*)," said I to myself, and I showed the drawing, Figure 1, to them. They both laughed heartily, and after they recovered told me I had failed to consider the force on the dielectric titanate.

This was a new idea to me, so I asked how much would that be, and would that spoil my invention? How could I figure it?

"Well," said one of them, "like you thought, there'll be no real or free charge on the titanate surface because $D_1=D_2$, but there will be an apparent surface charge $\sigma=\frac{1}{4\pi}(E_2-E_1)$ and there will be a force on account of that." "You mean an *apparent* force?" said I. "No," said he, "I mean a real force." "A *real* force on an *apparent* charge," I echoed, quite dazed.

"Bill," said the other, "Alter Ego is right. You can't have a real force on an apparent charge. What you really have is a polarization, P, in the titanate due to the molecules being made into dipoles by the electric field. Within the titanate the field is uniform so the force on the dipoles is zero. But at the surface the field is strongly nonuniform, in the X direction, so there is then a real force on the real dipoles there."

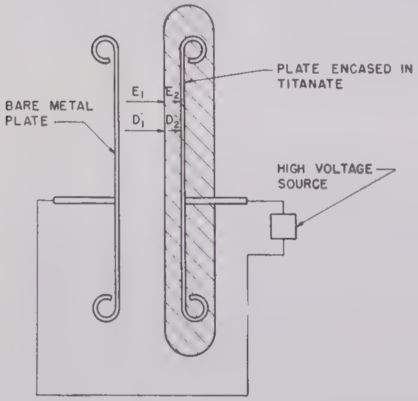

Figure 1. Electrostatic propellant for space ship

"Don't be metaphysical, Charlie," said Bill, "Here, I'll figure the thing out. We have

$$D=E+4\pi P \tag{1}$$

The real, volume charge density is

$$\rho=\frac{1}{4\pi}\frac{\delta D}{\delta x} \tag{2}$$

The apparent or polarization charge density is as in the following:

$$\rho'=-\frac{\delta P}{\delta x}=-\frac{1}{4\pi}\frac{\delta}{\delta x}(D-E) \tag{3}$$

The force per unit volume is then

$$f_B=[\rho+\rho']\,E=\left[\frac{1}{4\pi}\frac{\delta D}{\delta x}-\frac{1}{4\pi}\frac{\delta}{\delta x}(D-E)\right]E=\frac{1}{4\pi}\frac{\delta E}{\delta x}E=\frac{1}{8\pi}\frac{\delta}{\delta x}E^2 \tag{4b}$$

"Integrating from just outside the titanate to just inside, we get the following for the force per unit area at that surface,

$$F_B'=\int_1^2 f_B dx=\frac{1}{8\pi}(E_2^2-E_1^2) \tag{5b}$$

"Integrating from just outside the metal to just inside, we get for that surface

$$F_B''=\int_2^0 f_B dx=\frac{1}{8\pi}(0-E_2^2) \tag{6b}$$

"So the whole force per unit area of structure is then found to be

$$F=F_B'+F_B''=-\frac{1}{8\pi}E_1^2 \tag{7b}$$

which is just the negative of the force on Alter Ego's other metal plate, and so we can see that his invention won't work."

Charlie seemed impressed, but said, "Let's see how I do it with real polarization, P, but no force on the apparent charge, ρ'.

Instead of your equation 4*b* my equation for the force per unit volume will be

$$f_C=\rho E+P\frac{\delta E}{\delta x}=\frac{1}{4\pi}\frac{\delta D}{\delta x}E+\frac{1}{4\pi}(D-E)\frac{\delta E}{\delta x}=\frac{1}{8\pi}\frac{\delta}{\delta x}(2DE-E^2) \tag{4c}$$

"My force per unit area at the first surface will be, therefore,

$$F_C'=\int_1^2 f_C dx=\frac{1}{8\pi}(2D_2E_2-E_2^2)-\frac{1}{8\pi}(2D_1E_1-E_1^2)$$

$$=\frac{1}{8\pi}(2D_2E_2-E_2^2-E_1^2) \tag{5c}$$

"At the second surface I'll have

$$F_C''=\int_2^0 f_C dx=\frac{1}{8\pi}(0)-\frac{1}{8\pi}(2D_2E_2-E_2^2) \tag{6c}$$

"The total force per unit area will be

$$F=F_C'+F_C''=-\frac{1}{8\pi}E_1^2 \tag{7c}$$

"Your invention simply won't work, Alter Ego," Charlie and Bill both said, gleefully, with their arms around each other.

"Thank you, gentlemen," I said, glumly. "But I notice that Bill says that the force on the surface of the titanate tending to stretch the titanate is

$$F_B'=\frac{1}{8\pi}(E_2^2-E_1^2)=-\frac{1}{8\pi}E_1^2\left(1-\frac{1}{k}\right)^2 \qquad (5\mathbf{b}^1)$$

where k is the dielectric constant, while Charlie here says that it is

$$F_C'=\frac{1}{8\pi}(2D_2E_2-E_2^2-E_1^2)=-\frac{1}{8\pi}E_1^2\left(1-\frac{1}{k^2}\right) \qquad (5\mathbf{c}^1)$$

Now how much will the titanate actually be stretched? Until you gentlemen agree on that, I'll have to reserve my acceptance of your conclusion that my invention won't work." I stalked out, but I could hear them arguing violently with each other as to how much the titanate will be stretched.

Physicists are just as confusing as engineers.

How much will the tension on the titanate arising from the electric field be? Is Bill right, or is Charlie right?

J. Slepian, Alter Ego

It is interesting to examine a few textbooks or treatises on electromagnetism to see whether they agree with Bill or Charlie as to the force per unit volume on a dielectric in an electrostatic field.

Page and Adams, "Principles of Electricity," tenth printing, pages 48–9, give for an uncharged dielectric, $f=P\frac{\delta E}{\delta x}$ and agree with Charlie.

Abraham and Foeppl, "Theorie der Elektrizitaet," fourth edition, volume 1, page 48, give a formula, equation 16–1, which reduces for this one dimensional case to $f=\frac{1}{8\pi}\frac{\delta}{\delta x}(DE)$ and they agree with neither Bill nor Charlie. Abraham and Becker, "Electricity and Magnetism," page 95, for the special case of a material with an isotropic dielectric constant, k, which is independent of field strength and is a function of material density only, seem to find it necessary to add a term to the foregoing thus obtaining the formula $f=\frac{1}{8\pi}\frac{\delta}{\delta x}\left(DE+E^2\frac{\delta k}{\delta\sigma}\sigma\right)$ where σ is the density.

Stratton, "Electromagnetic Theory," and Jeans, "Mathematical Theory of Electricity and Magnetism," agree with Abraham and Becker for this special case.

Doesn't anybody agree with Bill? Yes, Richardson, "The Electron Theory of Matter," in equation 2, page 206, gives a formula which we find agrees with Bill's formula, $f=\frac{1}{8\pi}\frac{\delta}{\delta x}E^2$.

All these various formulations, however, will agree that Alter Ego's invention will not work. This is because for all of them the volume force is given as the gradient of a function, and for all of them, this function reduces to $\frac{1}{8\pi}E^2$ when $D=E$. However, they disagree as to what the "tension" in the titanate will be.

So again, how much "tension" will the electric field exert upon the titanate?

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Unbalanced Load

A balanced 3-phase star-connected resistance load is supplied from an efficient distribution system through a delta-star-connected transformer bank. The resistance in the supply system may be neglected. The resistance load is connected to the transformer bank by four short underground cables as indicated in Figure 1. The voltage drops 5.13 per cent when the load is connected to the transformer bank. A drill is accidentally driven through phase cables B and C and serious damage to these cables results from the short circuit. In attempting to maintain operations while replacement cables are being rushed to the job, the plant electrician connects the three resistors to the remaining sound phase cable as shown in Figure 2 and prepares to pour water on the transformer cases. However, he notes that the resistors develop only two-thirds the heat obtained in 3-phase operation. In attempting to increase the heating of the resistors, the electrician changes the connection of the neutral cable from the neutral connection of the transformer to phase B terminal as shown in Figure 3. He is disappointed to find, however, that the heaters are still developing only two-thirds the heat obtained in 3-phase operation.

Figure 1

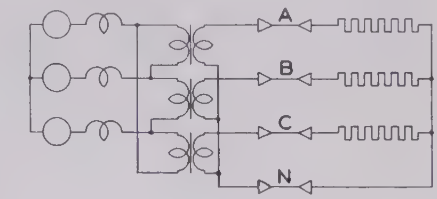


Figure 2

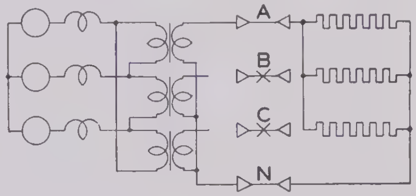
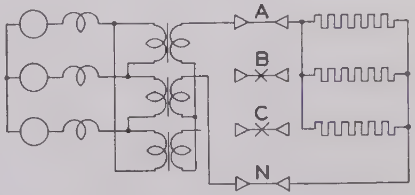


Figure 3



The electrician wants to know the answers to the following questions: What are the system characteristics? What else can he do to obtain at least 85 per cent normal heat in his equipment?

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Production Testing of Large D-C Apparatus

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ACCURATE ELECTRICAL TESTING for maintenance of quality control of d-c machines is highly desirable. To achieve this with the conventional load-run test methods necessitates that a good brush fit on the commutator be first established. Such fitting involves brush sanding, seating, and running under load until stability is obtained. This is a time-consuming and expensive process. The test here described offers a practical means of controlling the quality of the product in repetitive production. However, it neither obviates the necessity of load-testing in development work, nor of periodic load-testing as a check on quality in general production.

It is well known that the uniformity of the magnetic circuit in a given machine may be determined by checking its reluctance. This method has had wide commercial application for indicating the uniformity of the exciting flux-path variables within acceptable limits. In this new test method a no-load saturation curve is taken as a first step to control the variables affecting speed in a motor or voltage in a generator. By the proper selection of the values of excitation the variables can be separated into two groups: first, those which indicate the uniformity of the main flux-circuit reluctance; second, those which indicate the air-gap measurement.

This saturation curve is taken with the armature driven at a fixed speed. Unusual precautions are taken to indicate this speed accurately. The method used employs an oscilloscope to compare the frequency of an a-c tachometer with that of a standard 250-cycle-per-second tuning fork. A phase-shifting network is used to obtain a second 250-cycle-per-second frequency having a voltage lagging 90 degrees with respect to the original. These two are used for vertical and horizontal input to obtain a circular trace on the oscilloscope. The tachometer frequency is applied to the Z axis of the oscilloscope to modulate the circular trace, blanking out a small segment of the circle. When the two frequencies are properly synchronized the blanked-out portion will appear to stand still. The tachometer used has a ratio of 16 cycles per revolution. Therefore, one rpm of the oscilloscope indication represents only 1/16 rpm of the test motor. This makes visual indication of speed very accurate.

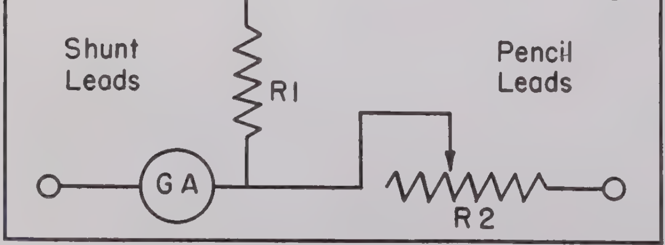

Figure 1. Simplified schematic diagram of compensation bridge circuit

The second step, which is somewhat unusual, is to take the same type of no-load saturation curve for the commutation flux circuit. To accomplish this, temporary small-diameter brushes are used in a pair of holders equally spaced from a main brush position, and at a sufficient distance from it to indicate the entire voltage induced by the commutating poles. The curve thus obtained is used as a means of indicating the uniformity of the commutating flux circuit reluctance. This, in turn, gives an indication of the grade of commutation to be expected, when compared to the same readings taken on a properly compensated machine. Data for this curve are taken with the armature driven at the same accurately indicated speed as used in the main flux circuit saturation curve.

The method of obtaining a reading of volts and amperes to indicate the commutation has been improved with the development of the compensation bridge circuit shown in Figure 1. This permits a direct reading of the ratio of volts to amperes, and thus offers a special advantage over the method of taking simultaneous readings of volts and amperes. The reluctance of a properly designed commutation-pole flux circuit is essentially constant, so the compensation-bridge ratio will be the same, even with small errors in the setting of the commutating field current. The bridge circuit as now used for commercial test is essentially the same as Figure 1 except that two protective resistors have been added, and a self-balancing bridge has been substituted for the galvanometer.

In the third step the machine is operated for the heating-up and bearing test at the load speed and with load current circulating in the armature and commutating field, but with no main-field excitation. In addition to preparing the armature for the high-voltage run and testing the bearings, this test has been found to be a good indication of the symmetry of the machine. Variations in the power necessary to drive the machine indicate the symmetry of the brushholders, the commutation poles, and the main poles.

The high-voltage run is made by driving the hot armature at ten per cent overspeed with the main fields excited to produce the peak voltage per bar required.

The remainder of the commercial test consists of the customary overspeed, high-potential, and hot-impedance tests.

Digest of paper 50-21, "Quick and Accurate Production Testing on Large D-C Apparatus," recommended by the AIEE Committee on Rotating Machinery and approved by the AIEE Technical Program Committee for presentation at the AIEE Winter General Meeting, New York, N. Y., January 30–February 3, 1950. Scheduled for publication in AIEE *Transactions*, volume 69, 1950.

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Magnetic Amplifiers of the Balance Detector Type

W. A. GEYGER

IN PRACTICAL APPLICATIONS of electronic amplifiers in the field of electrical measurements and control problems two serious disadvantages of tube amplifiers must be considered. First, the life of vacuum tubes is limited, and second, shocks or vibrations are dangerous to such tubes. In order to maintain the various advantages introduced by suitable use of electronic amplifiers and to avoid the serious disadvantages mentioned, a tubeless amplifier has been developed in different countries, namely, the magnetic amplifier, also called d-c controlled reactor, saturable reactor, and transductor. This amplifier consists of electric and saturable magnetic circuits so interlinked that a direct current controls the reactance of an a-c circuit. The magnetic amplifier, which is a real d-c amplifier containing no moving parts and not requiring any servicing, will be of great importance in future development of numerous technical fields offering rough working conditions. This amplifier will undoubtedly have extensive use, chiefly in the electrical control of military equipment, in commerce, and for control of various manufacturing processes and automatic devices for private use.

During the past 12 years, research activity in the field of magnetic amplifiers has been conducted toward the use of such amplifiers for the control of small reversing motors working in connection with servomechanisms. It is especially interesting to use a magnetic amplifier of the balance-detector type in the operation of self-balancing d-c potentiometers and d-c bridge networks. A special problem of the author's research work was replacing the mechanical converter and the electronic a-c amplifier used in high-speed recording potentiometers by a magnetic amplifier having polarized characteristics, high d-c sensitivity, and a large power gain. Therefore, the main problem consisted of developing a special magnetic amplifier having response characteristics of a balance detector as practically used in connection with d-c potentiometers and d-c bridge networks. This amplifier must have an extremely small drift rate and an output power sufficient for the control of a small reversing motor, which can be either a separately excited a-c motor of the induction-meter type or a d-c motor of the moving-coil meter type.

Magnetic amplifiers of the balance-detector type are based upon the use of symmetrical push-pull circuits which contain two balanced saturable-core reactor systems, both utilizing positive and negative feedback. There are different kinds of such push-pull circuits utilizing either external feedback (full-wave type) or self-saturation (half-wave type), but in all cases dry-disk rectifiers are provided for producing additional d-c magnetizations, proportional to the actual values of the two alternating load currents, and therefore producing corresponding positive or negative feedback effects. The resultant output current is duo-directional and is zero at zero input control current. This principle is especially interesting when several magnetic amplifier circuits are to be connected in cascade.

In practice it is required that fulfillment of the balance condition, output current = 0 if input current = 0, must be independent of changes in voltage, frequency, wave shape of the a-c supply, and changes in temperature. The magnetic amplifiers of the balance detector type, which were developed in Germany during World War II, were designed to operate at ambient temperatures between +70 degrees centigrade and −60 degrees centigrade for supply voltages of 30 to 40 volts and frequency ranges of 400 to 600 cycles per second. In single-stage and multistage amplifiers of this type the entire design revolves around the essential problem that the drift rate must be as small as possible.

In principle, magnetic-amplifier circuits containing a large amount of inductance have an inherently slow response time, and there is a certain time lag between the application of the input signal and the attainment of the full output load current. In certain practical applications this sluggishness of response due to "magnetic inertia" is not an important drawback, but in other applications, especially for high-performance servomechanisms and certain types of automatic control and instrument work, a very short response time is of paramount importance. As the minimum time delay will be of the order of one cycle of the a-c supply frequency (up to about 2,000 cycles per second), an obvious way to reduce the response time is to increase the supply frequency. Another efficient method consists of providing derivative feedback, which reduces the time of response to about one-fifth of its original value. Using this method in connection with a 400-cycle-per-second supply it would be possible to achieve a response time of about ten milliseconds or less.

The ratio K_P/T between power amplification K_P and time constant T is increased by the application of positive feedback. Furthermore, the time constant of a magnetic amplifier increases in direct proportion to the power amplification. When two or three stages of amplification are connected in cascade, the over-all power amplification is the product of the stage amplifications, whereas the total time constant is roughly the sum of the individual time constants. As the number of stages is increased there is an increase in the ratio of amplification to the time constant K_P/T. Therefore, in order to obtain a high value of this ratio, the design procedure would be, in many applications, to connect in cascade two or three stages, each stage having a comparatively low power amplification and yet using the maximum positive feedback that is consistent with the required stability of the amplifier.

Digest of paper **50-93**, "Magnetic Amplifiers of the Balance Detector Type," recommended by the AIEE Committee on Electronics and approved by the AIEE Technical Program Committee for presentation at the AIEE Winter General Meeting, New York, N. Y., January 30–February 3, 1950. Not scheduled for publication in AIEE *Transactions*.

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Electrical Maintenance Problems in Continuous Process Plants

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As a result of increased labor costs in recent years, continuous mass production methods are now employed in many industrial plants which formerly operated on a shift basis. The author points out the importance of making those changes in electric equipment existent in such plants which are necessary, but unfortunately often ignored or deferred, to provide for adequate maintenance under the new conditions of continuous usage.

FROM THE STANDPOINT of the electrical engineer, a continuous process may be defined as one requiring a continuous supply of electric energy to prevent excessive spoilage of the product. Even though individual production components may be shut down in sequence for routine maintenance, the over-all process usually requires that electric power be available at all times, year in and year out. Also, the small relative load required for each component usually prohibits sufficient segregation of electric circuits to permit simultaneous maintenance of the major electric equipment supplying that component. Consequently, the importance of providing reserve distribution facilities to permit adequate maintenance and repair of all electric apparatus becomes a major problem in design whenever such processes are involved. To provide such facilities at a minimum cost is a real problem and one to constantly test the mettle of the electrical engineer.

Until a few years ago continuous processes were largely confined to a relatively few specialized industries where the electrical problems were well understood and where provisions for adequate maintenance were incorporated in the initial design. This article is not intended to cover the problems of such industries as there is a wealth of excellent literature available on the subject.

However, rising labor costs in recent years have forced the adoption of continuous mass production methods in many industrial plants which heretofore had operated entirely on a shift basis. Usually the existing electric distribution systems in such plants were of the simplest possible type since continuity of service was not of particular importance and there was ample time available on the night shift and on the week ends to perform necessary maintenance work. All too frequently the complexity of the changes required to these distribution systems to permit maintenance of the electric equipment and circuits supplying the new processes have been overlooked or ignored.

Unfortunately, it also seems to be all too common in such cases for the management to defer indefinitely even those changes to the electric system necessary for either minimum maintenance or to insure reasonable continuity of service. Hence, it is not unusual today to find cases where the electric equipment has not been adequately inspected for several years as it was impossible to release the equipment without shutting down a critical process.

It is up to the electrical engineer to determine the absolute minimum of changes in the distribution system required, not only to permit reasonable maintenance, but also to insure reasonable continuity of service. Fortunately, the solution of one problem usually solves the other. He must then utilize every means at his disposal to convince his management that the proposed changes are necessary and desirable if expensive production losses are to be avoided. This article is intended to assist the engineer in meeting the first requirement.

ANALYSIS OF PROBLEM

It is most essential for the electrical engineer to work closely with the process engineers so as to insure a well-co-ordinated over-all design that will not impose undue limitations on the distribution system. Frequently such collaboration will result in a materially less complicated and less expensive over-all installation. In this respect, therefore, it is well for the engineer to keep the following requirements in mind:

(*a*). Processes should be so designed and operated that short interruptions of electric power will not result in an appreciable spoilage of product. In most instances it will be found that interruptions of not more than 15 or 20 minutes duration can be accommodated without undue complications. This will cover the great majority of service interruptions but, of course, will not permit any major maintenance work to be performed. It does, however, permit ample time for transferring to an auxiliary source of power.

(*b*). Gradual voltage variations are inherent in any electric distribution system but they may be readily compensated for by induction regulators, by transformers with automatic load ratio control, or by other well-known means. However, designers of process equipment frequently do not consider the possible effects of momentary voltage fluctuations caused by switching or lightning surges or by external systems faults. Although relatively infrequent, such fluctuations can be quite severe and may cause the drop-out of motor controllers on undervoltage, thus shutting down some critical portion of the process, or else the momentary changes in motor torque or speed induced by such fluctuations may result in spoilage of the product. While they can and will occur on any electric system, it naturally

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Full text of a revised version of a conference paper, "Electrical Maintenance Problems in Continuous Process Plants," originally presented at the AIEE Fall General Meeting, Cincinnati, Ohio, October 17–21, 1949.

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follows that the more comprehensive the system the greater the frequency of such fluctuations. This is especially true if the plant is supplied from a public utility, since a major disturbance frequently will cause a voltage fluctuation over the entire utility system. Dropout of motor controllers on momentary undervoltage may be readily overcome by providing the controllers of all critical motors with time delay undervoltage protection and thus enabling them to override the disturbance. Unfortunately, the solution of the second problem caused by momentary changes in motor torque or speed is not so simple. The only real solution is to design the process so that it will be as insensitive as possible to such changes.

(*c*). Process designs adversely affected by minor changes in frequency should be avoided at all costs. Maintenance of an exact frequency is virtually impossible, even on large utility systems.

(*d*). Provision should be made for inspecting all contact making equipment such as circuit breakers and switches at least once a year.

(*e*). The insulation resistance of all electric equipment should be checked at least twice a year, and preferably monthly.

The foregoing requirements may seem obvious at first but a surprising number of installations have been found to require major and expensive modifications because of product spoilage which has been caused by a definite failure to observe these limitations. Strict adherence to these requirements also will make the problems of the electrical engineer infinitely easier.

The great majority of existing industrial plants are supplied from simple radial distribution systems with little or no provision for duplicate service to a particular load. Essentially, the problem covered herein resolves itself into providing such duplicate service to all critical loads at the least possible expense. An adequate solution requires that consideration be given to each and every major component of the distribution system.

CONTINUITY OF SERVICE REQUIREMENTS

The first step should be the tabulation of all existing and contemplated loads, preferably by processes or by departments. Each load then should be carefully analyzed by all concerned to determine whether loss of electric power will result in a significant spoilage of product and, if so, what the minimum outage period should be to avoid excessive spoilage. It usually will be necessary for management to establish an arbitrary factor for determining what constitutes excessive spoilage.

The loads then should be broken down into three groups as follows:

1. Essential loads where outages of more than a relatively few minutes (15, 20, or 30 minutes) cannot be tolerated.
2. Moderately essential loads where outages of more than a few hours cannot be tolerated.
3. Nonessential loads.

It will be helpful to list the loads in each category in the order of importance to assist in restoring service in case of a complete outage of the distribution system, or in case a shortage of power occurs and thus forces curtailment of operations.

The importance of careful analysis in this phase of the problem cannot be overemphasized. Any possible reduction which can be made in the total essential load will decrease the extent of the changes to the distribution system and thus frequently will result in effecting substantial savings in the over-all cost.

POWER SOURCE

Power sources for industrial plants may be grouped into three major classifications: those purchasing all their power requirements from the public utility; those generating a portion of their requirements and purchasing the balance; and those generating all their requirements in their own power plant.

Most industrial plants come under the first of the above classifications, but there is an increasing trend toward the second classification in plants where process steam requirements permit economical generation with back pressure or bleeder turbines. Comparatively few plants today can justify generating all of their requirements.

Determination of the adequacy of a public utility supply requires close collaboration with the utility engineers. Once the problem is understood, they will be in a position to make specific suggestions and recommendations that usually reduce the problem materially. A careful analysis frequently will show that a complete duplicate source of power is unwarranted. In most cases the reserve source need only have capacity sufficient to carry the essential loads, the nonessential loads being disconnected either manually or by means of time delay relays. Generally, this reserve source can be provided by an emergency connection to another utility feeder supplied from another point in the system.

A great deal always will depend upon the frequency and duration of faults on the utility system, especially those on the feeder supplying the plant. Generally speaking, the frequency of faults is higher on overhead open-wire lines but the duration is much less than for underground cables. Also, most of the faults on open-wire lines are of a temporary nature and outages due to such causes can be greatly alleviated by the judicious use of automatic reclosing circuit breakers.

Plants in the second classification usually can carry their essential loads either on the public utility feeder or on their local generators. In such cases the provision of a reserve supply from the utility system is hardly warranted.

Plants in the third classification require careful study to ensure that sufficient generating capacity is always operating to carry the essential loads. This means that the number and size of generators should be such that the essential load can be carried in case of the outage of the second largest unit at a time when the largest unit is undergoing repair.

PRIMARY SUBSTATION

The primary substation customarily includes the incoming source of power, the step-down transformers, if any, and the primary switchgear for controlling the primary feeders within the plant. It is unfortunate that this equipment, which really constitutes the heart of the distribution system, generally receives the least maintenance because of the cost of providing duplicate facilities. Unless such facilities are installed, any maintenance usually requires the shutdown of the entire plant, which is difficult to arrange.

This difficulty becomes almost an impossibility whenever major continuous processes are involved, and the engineer should utilize every means at his disposal to provide sufficient facilities in order to allow adequate maintenance at all times.

It is generally rather simple to arrange for proper maintenance of the incoming source of power as the essential loads can be transferred to the reserve source during such periods without undue hardship—especially over week ends and holidays.

Duplicate step-down transformers are rather difficult to justify except for very essential loads or where atmospheric conditions require frequent cleaning of insulators and bushings. Most transformers require comparatively little maintenance, except for periodic testing and reconditioning of the insulating oil. This work can be handled readily with the transformer in service. Many utilities today maintain either mobile transformers or a stock of spare transformers for use on their system and often arrangements can be made to utilize such equipment whenever extensive repairs are required.

If reserve equipment is not readily available, then there is much to recommend the use of single-phase units. If delta-connected, the bank may be operated in open delta for extensive repairs to any one transformer. It is important that the normal load under such a condition be limited to not more than 57.7 per cent of the delta capacity. However, advantage can be taken of the overload capacity of the transformers to carry peak loads in excess of the reduced rating for an hour or two each day. If the essential and moderately essential load is too large, then a spare transformer unit is justified.

Most industrial plants, including many with large continuous processes, have only a single primary bus. Since a shutdown of the entire plant is required to de-energize this bus, it is extremely doubtful if many of these installations receive proper maintenance; and it becomes extremely difficult to add to or modify the primary switchgear for the same reason. Therefore, it is almost essential that continuous process plants be provided with some means for sectionalizing the primary busses, even if only by disconnect switches, and that each bus section be independently supplied from the incoming power source or step-down transformer bank. It may be possible to rearrange the primary feeder circuits so as to release sufficient circuit breakers for this purpose without the necessity of having to purchase additional equipment.

PRIMARY DISTRIBUTION

Primary distribution systems in existing plants are generally of the simple radial type with little or no provision for duplicate supply to the secondary substations. The feeder arrangement is usually such that loads are served on an area basis with little or no regard for the type of load supplied. The extent of the duplicate feeder capacity required can be reduced materially by segregating the nonessential loads onto certain feeders. Such segregation will permit rapid disconnecting of the nonessential load whenever the reserve power source must be used. A careful analysis of the situation will show that often the major portion of such load can be so transferred with a moderate amount of reconnection.

Both continuity of service and maintenance requirements will generally dictate the provision of duplicate supplies to all substations serving essential loads. The two basic methods commonly employed consist of either duplicate feeders or the creation of loop feeders by tying the extremities of two or more feeders together through sectionalizing circuit breakers. There are, of course, almost as many variations and combinations of these two schemes as there are industrial plants.

Whichever scheme is used, it is most essential that the feeder arrangement be such that all essential loads are supplied from at least two sources such as separate bus sections in the primary substation. In this way any cable, circuit breaker, or other apparatus supplying essential loads may be removed from service for inspection and maintenance without affecting operations. Since the shutdown of a feeder for maintenance or repair is comparatively infrequent, considerable savings may be realized by taking full advantage of the overload capacities inherent in the equipment. Further economies can be effected by arranging the transfer facilities so that the load released by de-energizing a feeder will be distributed over two or more of the remaining feeders and thus will allow the normal loads to approach the feeder rating.

SECONDARY SUBSTATIONS AND DISTRIBUTION

The rapidly increasing trend toward multiple secondary substations of moderate capacity has increased the maintenance problem. Generally, such substations are of the single transformer type and the provision of duplicate facilities is difficult, if not impossible, to justify. However, much can be accomplished by the judicious use of secondary interconnections.

These suggested interconnections also may be utilized to provide duplicate service to the distribution centers. Considerable care is necessary in applying them, however, to avoid excessive short-circuit currents in the secondary system. Generally, the safest procedure is to operate such interconnections normally open.

Whenever possible, the secondary distribution centers should be so allocated that each essential load component will be served by a separate center. In this manner normal maintenance on the centers may be performed in conjunction with the maintenance of the process equipment. There is little justification for providing duplicate facilities beyond the distribution centers if they are so applied.

CONCLUSIONS

This article has attempted to summarize some of the problems generally encountered in providing for the maintenance of electric equipment in plants employing continuous processes and to point out basic solutions for them. The discussion was purposely kept on a broad plane because each and every industry, and even every individual plant, has special problems of its own. However, by following the principles given in this article it will be found that economical solutions can be devised to meet almost any situation which may occur.

INSTITUTE ACTIVITIES

Great Lakes District Meeting to Have Comprehensive Program

The AIEE Great Lakes District Meeting, to be held at the Hotel Hayes in Jackson, Mich., May 11 and 12, 1950, will cover the subjects of motors, magnetic amplifiers, distribution, generation, transmission, metering, and student papers, both by graduates and undergraduates. Inspection trips for both days have been arranged and these inspection trips are closely allied with the subject matter on the technical program.

Arrangements for graduate students' technical papers and undergraduate students' technical papers have been made, so that there will be a complete program for students throughout the two days of the meeting.

On the social side, there will be an informal banquet the first evening for everyone and a students' luncheon and students' banquet will be held to complete the students' program. There will also be special entertainment for the ladies at the meeting on both days.

The technical meetings will be held at the Hotel Hayes and the students' activities for the main part will be held at the Otsego Hotel, with one meeting being scheduled for the Public Library Auditorium. The subjects of the various sessions and the tentative titles and authors of the papers to be presented at these meetings will be found in the program.

One of the papers, entitled "Transmission Substation Design—A Departure From the Usual," will deal with some of the design features of the Verona Transmission Substation at Battle Creek on the Consumers

Tentative Technical Program

Great Lakes District Meeting, Jackson, Mich., May 11–12

Thursday, May 11

9:00 a.m. Registration

10:30 a.m. General Meeting

12:30 p.m. Luncheon

2:00 p.m. Motors

DP. The Goerges Phenomenon—Induction Motors With Unbalanced Rotor Impedances.** *H. L. Garbarino*, General Electric Company; *E. T. B. Gross*, Illinois Institute of Technology

DP. Application of Motors and Control to Air Compressor Drive.** *G. F. Johnson*, Joy Manufacturing Company

DP. Commutation in Universal-Type Motors.** *L. C. Packer*, Westinghouse Electric Corporation

2:00 p.m. Magnetic Amplifiers

50-123. Series-Connected Saturable Reactor With Control Source of Comparatively Low Impedance. *H. F. Storm*, General Electric Company

DP. Application of Magnetic Amplifiers.** *F. N. McClure*, Westinghouse Electric Corporation

DP. Comparison of Graphical Analysis of Magnetic and Vacuum Tube Amplifiers.** *R. E. Lee*, Westinghouse Electric Corporation

2:00 p.m. Distribution

DP. Design of Rural Electric System.** *C. M. Stanley*, Stanley Engineering Company

50-124–ACO.* Future Planning for a 13,800-Volt Subtransmission System and Associated Rural Distribution Systems. *R. W. Brown*, Interstate Power Company

DP. Practical Experiences With Resonant Grounding in a Large 34.5-Kv System.** *H. H. Brown*, Wisconsin-Michigan Power Company; *E. T. B. Gross*, Illinois Institute of Technology

50-125. Effects of Supply Line Unbalance on the Filtered Output Ripple of Polyphase Rectifiers. *C. K. Hooper*, *C. H. McAdie*, Westinghouse Electric Corporation

DP. Voltage Regulation of Suburban and Rural Feeders.** *W. L. Peterson*, Allis-Chalmers Manufacturing Company

2:00 p.m. Graduate Student Technical Papers

Public Library Auditorium

2:00 p.m. Inspection Trip to Consumers Power Company—Bryce E. Morrow Plant

6:30 p.m. Banquet—Informal

Ball Room, Hotel Hayes

Friday, May 12

9:30 a.m. Generation

DP. Modern Power Supply Facilities.** *J. H. Foote*, Commonwealth Services, Inc.

DP. Problems in the Design and Application of Large Turbine Generators.** *A. A. Johnson*, *M. D. Ross*, Westinghouse Electric Corporation

DP. Telephone Influence Factor in Synchronous Machines.** *I. C. Benson*, *G. L. Oscarson*, Electric Machinery Manufacturing Company

DP. High-Voltage Generator Insulation.** *G. L. Moses*, Westinghouse Electric Corporation

9:30 a.m. Transmission

DP. Operating Experience With Resonant Grounding in Power Systems in the United States (A Survey Report).** *E. T. B. Gross*, Illinois Institute of Technology; *E. W. Atherton*, Railway and Industrial Engineering Company

DP. Progress Report of Utilities Research Commission Investigation of Galloping Conductors.** *F. E. Andrews*, *E. L. Tornquist*, Public Service Company of Northern Illinois

DP. Design and Construction of 69-Kv Transmission Structures.** *R. G. Yerk*, Hughes Brothers

9:30 a.m. Student Technical Papers

Otsego Hotel

12:30 p.m. Student Luncheon

Otsego Hotel

2:00 p.m. Transmission

DP. Transmission Substation Design—A Departure From the Usual.** *E. V. Sayles*, Consumers Power Company

DP. Increasing the Voltage of a Subtransmission Network From 24 Kv to 40 Kv.** *Philip Holz*, *G. A. Strohmer*, Detroit Edison Company

DP. Cathodic Protection of Buried Metal Structures.** *R. L. Featherly*, Dowell, Inc.

2:00 p.m. Distribution

50-126–ACO.* Meter Operating Problems of a Public Utility. *J. C. Langdell*, Commonwealth Services, Inc.

DP. Banking of Transformer Secondaries.** *J. A. Strelzoff*, Michigan State College

50-127. A New High-Interrupting-Capacity Low-Voltage Power Fuse. *C. L. Schuck*, General Electric Company

DP. Chemical Brush Control on Rural Power Systems.** *C. J. Waldron*, Rural Electrification Administration

DP. Noise Evaluation of Fluorescent Lamp Ballasts.** *C. P. Hayes*, *H. R. Gould*, General Electric Company

2:00 p.m. Inspection Trip—Jackson

2:00 p.m. Student Technical Papers

Ball Room, Otsego Hotel

6:30 p.m. Student Banquet

Ball Room, Otsego Hotel

—PAMPHLET reproductions of authors' manuscripts of the numbered papers listed in the program may be obtained as noted in the following paragraphs.

—PRICES for papers, irrespective of length, are 30 cents to members (60 cents to nonmembers) whether ordered by mail or purchased at the meeting. Mail orders are advisable, particularly from out-of-town members, as an adequate supply of each paper at the meeting cannot be assured. Only numbered papers are available in pamphlet form.

—COUPON books in 9-dollar denominations are available for those who may wish this convenient form of remittance.

—THE PAPERS regularly approved by the Technical Program Committee ultimately will be published in Proceedings and Transactions; also, each is scheduled to be published in Electrical Engineering in digest or other form.

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* **ACO:** Advance copies only available; not intended for publication in *Transactions*.

** **DP:** District paper; no advance copies are available; not intended for publication in *Transactions*.

Power Company system. The Verona Transmission Substation is the subject for the cover of this issue of *Electrical Engineering* and it is intended to include this substation in the inspection trip which will be taken to the Bryce E. Morrow Plant at Kalamazoo, Mich., on Thursday, May 11.

The Bryce E. Morrow Steam Plant is one of the recent Consumers Power Company steam plants and in general embodies the design features of all the recent generating plants built on the Consumers Power Company's system. This generating station, which is located on the Kalamazoo River, has a name-plate rating of 180,000 kw. Other stops will be made along the itinerary in addition to the previously mentioned Verona Substation.

It is planned to have the inspection trip for Friday afternoon cover some of the plants in Jackson. Such plants may include the Sparton Radio Plant and the Goodyear Tire Factory.

Reservations have been made at the Jackson Country Club for the playing of golf on both days of the meeting. The Committee on Entertainment would appreciate being advised on the mailed registration card as to whether the registrant desires to play golf.

Arrangements have been made for a sight-seeing trip for the ladies which will take them as far as Battle Creek and on a tour through the W. K. Kellogg Company Food Plant there on May 12. A tour of the Gilbert Chocolate Factory in Jackson is scheduled for May 11. Otherwise, the program remains the same as that previously announced, including a luncheon, card games, golf, and other entertainment, besides attendance at the main banquet which will be held on the evening of May 11 at the Hotel Hayes.

For more complete details, including data on hotel rates and reservations, see the March issue of *Electrical Engineering* (*p 265*).

Varied Program Promised for Visitors to Summer and Pacific General Meeting

The 1950 AIEE Summer and Pacific General Meeting, which will be held in Pasadena, Calif., June 12–16, promises a technical program of broad interest, with opportunity for inspection trips, sports, and social recreation. In addition, Pasadena, which is adjacent to Los Angeles, affords unlimited opportunity for healthful outdoor enjoyment.

The committee suggests that those who wish to see the Grand Canyon en route to Pasadena travel via the Santa Fe, since this railroad has a through car which stops over at the Grand Canyon. The Santa Fe also runs directly through Pasadena. The Union Pacific goes through Las Vegas and for those traveling by this railroad, it is possible to make a stopover to see the Hoover Dam Power Plant. In traveling on the Union Pacific, passengers should detrain at East Los Angeles, where busses will be available to take them to Pasadena. Likewise, those arriving on the Southern Pacific Lines should detrain at Alhambra, where busses will take them to Pasadena also. In both instances reservations should read through to Pasadena.

INSPECTION TRIPS

Fourteen exceedingly interesting inspection trips have been arranged by the committee in charge for the information and pleasure of the members attending. At the Florida exchange of the Sunland-Tujunga Telephone Company, one of the most complete installations of automatic toll ticketing and automatic toll accounting procedures will be demonstrated. At the Walt Disney Studios, visitors will be shown how the studio operates, from the development of the story to the review theater. A tour through the two large downtown Los Angeles buildings of the Pacific Telephone and Telegraph Company will afford an opportunity for members to see in operation Southern California's largest communications center. At the Lockheed Aircraft Corporation plant in Burbank, home of the famous *P-38 Interceptor*, *F-80 Jet Fighter*, and *Constellation* transport airplanes, it will be possible to see extensive plant facilities, manufacturing methods, and lines of airplanes in current production.

The world-renowned Mount Wilson observatory and television stations, to be the subject of an early evening trip during the AIEE Summer and Pacific General Meeting

The inspection trip to the studios of station *KFI-TV* will not only include the studio, associated control room, and other equipment, but also participation in a daytime television program. At the Fontana Works of the Kaiser Steel Corporation will be seen the only steel mill on the Coast with its own coke ovens and blast furnaces, as well as open hearth furnaces and steel finishing facilities. A tour of the California Institute of Technology campus will include the Analogue and IBM Digital Computors and a demonstration of high-voltage and dielectric investigations. An early evening trip will be made to the world-renowned Mount Wilson Observatory and Television Stations. In order to see the Palomar Observatory, a special all-day trip has been arranged. The total round-trip distance from Pasadena by bus is 260 miles, and it is suggested that the trip be undertaken only by those who will suffer no ill effects from the time and distance involved in such long rides.

Visitors to the Pasadena meeting should not miss seeing the University of California at Los Angeles because of the outstanding architecture of its buildings and the spaciousness of its campus. At the Redondo Steam Station of the Southern California Edison Company ocean water, used in vast quantities for cooling purposes, is pumped to and from the station through two submarine tunnels extending 1,900 feet into the sea along the ocean bottom. At the Mesa Substation of this company will be seen the terminating and switching apparatus for the carrier current equipment used for communication and load telemetering purposes. At the Harbor Steam Plant of the City of Los Angeles Department of Water and Power is the largest municipally owned steam plant in the United States. Also to be visited is Receiving Station *E* where the Hoover transmission voltage is stepped down from 287 kv to 132 kv.

HOUSING ACCOMMODATIONS

All of the housing accommodations except those at the California Institute of Technology have a deadline for reservations of June 1, so it is essential to write for reservations, utilizing the following hotel information. Address: Earl S. Condon, 1151 South Broadway, Los Angeles 15, Calif. Names of individuals and arrival time must be included.

The Huntington Hotel is the headquarters of the Summer and Pacific General Meeting and the technical sessions and the committee meetings will be held there. The somewhat limited capacity of the Huntington has been reserved for the Institute officers and Section and District representatives.

Huntington Hotel. Maximum rates based on double occupancy of each room will be $12–$14 per day per person American plan. To utilize the Huntington accommodations to the fullest extent there will be a number of twin double rooms requiring double occupancy in each. These rooms have a bath off a private passageway between rooms.

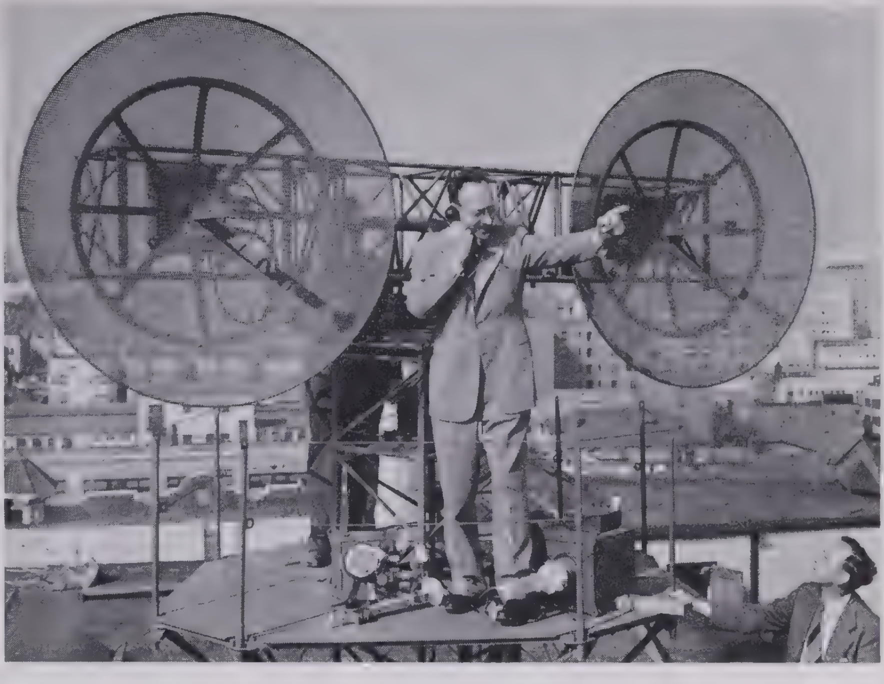
Constance Hotel—Pasadena. (Within two miles of the Huntington.) Rates are $5 per day single, $7–$8 per day double European plan; private bath with every room.

Green Hotel—Pasadena. (Within 2½ miles of the Huntington.) Rates are $7 per day for double occupancy, European plan. Some suites (two double rooms with bath between) are available at the same rate.

Pasadena Motels. Recommended for visitors with cars, the rates and facilities are variable. Average rates are $4 single, $5.50 double, $7 triple, $8.50 quadruple.

California Institute of Technology—Pasadena. (About one mile from hotel.) Offers dormitory rooms on campus, single occupancy only $3 per day, bath with each 4-room group. Garage is free. Breakfast is available in cafeteria on the campus.

Los Angeles Biltmore. (About ten miles and one-half hour from Huntington via Pasadena Freeway.) It is strongly suggested that occupancy start Sunday, June 11. Singles are $7–$10 per day; double, $9.50–$14 per day; suites $18–$24 and $30 per day, European plan. All have private baths.



Los Angeles terminal, on roof of the Mutual Building, of the Los Angeles-Catalina Island radio link—which may be visited during the AIEE Summer and Pacific General Meeting in Pasadena, Calif.

Future AIEE Meetings

AIEE Conference on Electrical Engineering Problems in the Rubber and Plastics Industries
Portage Hotel, Akron, Ohio
May 5, 1950

Conference on Improved Quality Electronic Components
Department of Interior Auditorium
Washington, D. C.
May 9–11, 1950

Great Lakes District Meeting
Hotel Hayes, Jackson, Mich.
May 11–12, 1950
(Final date for submitting papers—closed)

Conference on Telemetering
Benjamin Franklin Hotel, Philadelphia, Pa.
May 24–26, 1950

Summer and Pacific General Meeting
Huntington Hotel, Pasadena, Calif.
June 12–16, 1950
(Final date for submitting papers—closed)

Middle Eastern District Meeting
Lord Baltimore Hotel, Baltimore, Md.
October 3–5, 1950
(Final date for submitting papers—July 5)

Fall General Meeting
Skirvin Hotel, Oklahoma City, Okla.
October 23–27, 1950
(Final date for submitting papers—July 25)

1951 Winter General Meeting
New York, N. Y.
January 22–26, 1951
(Final date for submitting papers—October 24)

All reservations must be vacated not later than Saturday, June 17, because the National Shrine Convention has reserved all available hotel accommodations within a 100-mile radius of Los Angeles.

Transportation between the official hotels listed and the Huntington Hotel Headquarters will be available at a nominal charge, covering the complete scheduled day and evening activities. Electric interurban service at frequent intervals is available between all hotels and the Huntington.

ENTERTAINMENT

On Monday, June 12, a noon luncheon will be held in the banquet room of the Huntington Hotel. Arrangements are being made for a speaker of national prominence who will speak on a subject of immediate interest to all in attendance. In the evening at 8 p.m. a program of motion pictures will be presented in the theater of the Huntington Hotel. Included on the program will be full-color movies of the January 2, 1950, Tournament of Roses Parade. Admission will be free to those in attendance at the convention.

Tuesday, June 13, will include an informal barbecue and Aquacade Show to be held around the beautiful Huntington Hotel pool in the evening. The Aquacade will consist of beautiful and spectacular performances by expert swimmers and divers, including stars from the American Olympic Team. Following the show, there will be an informal reception for the President on the terrace overlooking the pool.

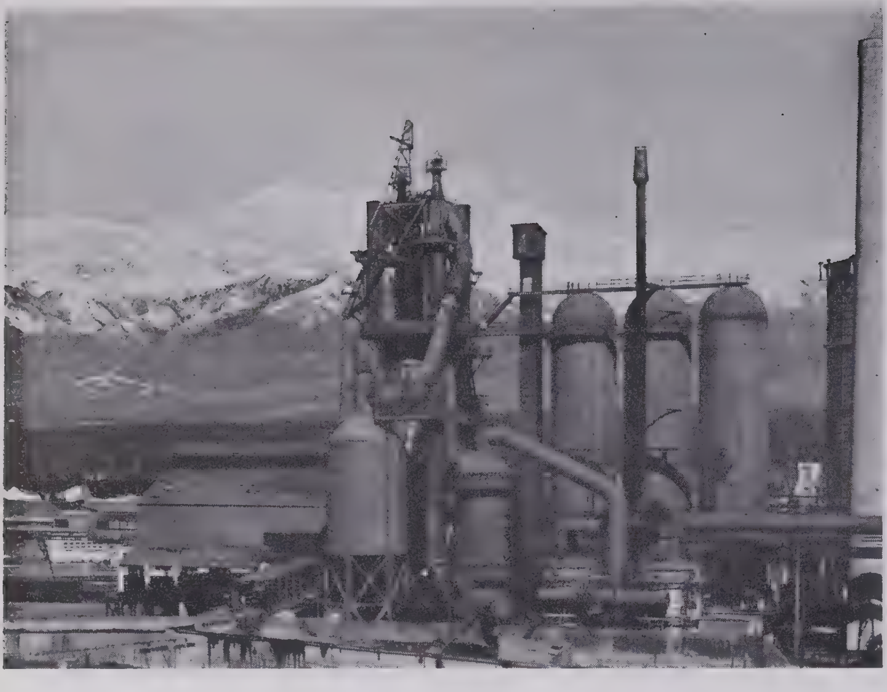
The inspection trip to Mount Wilson will be held on Wednesday and on Thursday evening the banquet will be held on the terraces around the Huntington Hotel pool. The show has been arranged to feature well-known stars of the screen, radio, and television. Since the Huntington Hotel is noted for its excellent cuisine, and Los Angeles is the entertainment capital of the world, it is certain that this night should prove to be the highlight of the meeting. Dress will be informal for this affair as well as all other entertainment features at the Summer Meeting. No events will be scheduled which will require formal dress for either the ladies or gentlemen. It is suggested that the ladies provide themselves with light wraps for these outdoor evening activities.

In addition to the afore-scheduled entertainment, tickets for radio shows, television shows, and other local entertainment will be available and arrangements for a wide variety of entertainment can be made at the information desk in the lobby of the Huntington Hotel.

LADIES' EVENTS

An interesting week of entertainment will begin for the ladies attending with an informal garden tea on Monday afternoon at the Hotel Huntington. For Tuesday, a tour has been planned through Hollywood and Beverly Hills where homes of various motion picture celebrities may be seen, with a short stop at Grauman's Chinese Theater to see the footprints of the stars. Continuing via Sunset Boulevard towards the ocean and past the University of California at Los Angeles, the group will stop for luncheon at the Club Del Mar at Santa Monica, on the Pacific Ocean. The return trip will be via Wilshire Boulevard, the locale of some of Southern California's smartest shops.

On Wednesday afternoon, June 14, a tour of Pasadena will be taken, including visits to the world-famous Huntington Library, Art Gallery, and Botanical Gardens in San Marino, and also to the historic old Mission San Gabriel. Thursday morning will be devoted to a trip through California's



"Bess Number 1," one of two 1,200-ton capacity blast furnaces of the Kaiser Steel Corporation at Fontana, scheduled for inspection during the coming AIEE Summer and Pacific General Meeting. In the background are the Sierra Madre Mountains

famous orange groves, ending with a conducted tour of an orange packing plant. An audience participation show has been arranged for the afternoon by television station *KFI-TV*.

Time for visiting and shopping has also been allowed and arrangements for other activities may be made on request to the Committee of Ladies at the Information Desk.

SPORTS

Golf (*for men only*). The Annual Golf Tournament will be a one-day 18-hole tournament at Pasadena's Brookside Park, in the shadow of the Rose Bowl. It will be held on Tuesday morning, June 13. For AIEE members, there will be an 18-hole medal play at handicap for the Mershon Trophy Low Gross, Low Net on Kickers Handicap Prizes. Pacific Coast AIEE members will play 18 holes at handicap for the Fisken Cup.

Annual Meeting

The annual meeting of the American Institute of Electrical Engineers will be held in Pasadena, Calif., at 10:00 a.m., Monday, June 12, 1950, during the Summer and Pacific General Meeting.

At this meeting the annual report of the Board of Directors and the reports of the Committee of Tellers on the ballot cast for the election of officers will be presented. The Lamme Medal will be presented to C. M. Laffoon (A '24, M '39, F '45).

Such other business, if any, as properly may come before the annual meeting may be considered.

Signed H. H. HENLINE
Secretary

Tennis. There are two excellent courts at the Huntington Hotel and it is planned to have a Men's Singles and Doubles Tournament for members and registered guests. Members in the Singles will compete for the Mershon Trophy, and prizes will be awarded for the winner and the runner-up in both the Singles and the Doubles Tournaments.

STUDENT ACTIVITIES

Technical sessions featuring papers presented by students are scheduled for 9:00 a.m. on both Thursday and Friday. Both of these Student Technical Sessions will be held at the California Institute of Technology. At 12 noon on Thursday a student luncheon will be held at the Athenium on the campus of the California Institute of Technology, to be attended by representatives and Counselors. A prominent speaker is promised for this occasion. The Prize Paper Session will be held at the California Institute of Technology at 3:00 p.m. on Thursday. This year the winners of District Branch prizes from the even-numbered Districts will be invited to represent their prize-winning papers.

Program Issued for Conference on Rubber and Plastics Industries

As announced previously, the third annual Conference on Electrical Engineering Problems in the Rubber and Plastics Industries will be held in Akron, Ohio, on Friday, May 5, from 8:00 a.m. to 5:30 p.m. Headquarters will be at the Hotel Portage. This conference is being sponsored by the AIEE Subcommittee on Rubber and Plastics Industries (of the General Applications Committee) in co-operation with the AIEE Akron Section.

Advance registration is requested, through use of the mailed registration card, to conserve time at the one-day conference. The registration fee, for both members and nonmembers of AIEE, of $1.50 is required in order to make the conference financially self-supporting. Reservations for the luncheon to be held in the Hotel Portage at 12:00 noon at $2 per plate also should be indicated on the mailed card. The luncheon reservations must be made and paid for by Wednesday, April 19.

Advance copies of the individual conference papers will not be published. However, all of the papers will be included in a single booklet, copies of which may be reserved. Prices for the booklet will be determined by printing costs, to be billed when booklets are mailed. (Previous issues were $1.50 for AIEE members and $3 for nonmembers.)

When the registration and reservation card has been completed it should be returned to: W. R. Wagner, 105 Fir Hill, Akron 4, Ohio. Mr. Wagner also will supply additional registration cards upon request. Checks or money orders should be made payable to: Akron Section AIEE.

Persons desiring hotel reservations in Akron should communicate directly with the hotels. The Hotel Portage offers single rooms from $3.50 per day up; the Hotel Mayflower, from $3.85 per day and up.

The personnel of the AIEE Subcommittee on Rubber and Plastics Industries is as follows:

R. F. Snyder, *Chairman*, A. T. Bacheler, B. J. Dalton, J. Gammell, K. W. John, G. V. Kullgren, J. F. Moore, B. J. Morgan, W. L. Ringland, V. S. Sywulka, O. M. Bundy, W. S. Watkins, C. E. Robinson, R. G. Rudrow, H. J. Sucrest, R. E. Seddon, H. L. Smith

The Committee on Local Arrangements consists of:

A. G. Seifried, *Chairman;* W. R. Wagner, *Secretary-Treasurer;* F. A. Green, F. J. Ilse, H. G. Shively

The one-day program for the conference is as follows:

Morning Session

Calender Auxiliary Drives Including Constant Tension Winder Drives for Film and Fabric. *I. E. Andreasen*, General Electric Company, Schenectady, N. Y.

Industrial Lighting of Factory and Office for Rubber and Plastic Plants. *E. A. Linsday*, General Electric Company, Cleveland, Ohio

Choice of Motor Speeds for Rubber Mill Room Service. *J. H. Skeen*, United States Rubber Company, New York, N. Y.

Recent Developments in Process Sequence Control. *E. B. Sutherland*, Emmett Machine Company, Akron, Ohio; *T. C. Jones*, National Rubber Machinery, Akron, Ohio

12:00–1:30 p.m. Luncheon

Afternoon Session

The Role of Electronics in the Rubber and Plastics Industries. *E. H. Vedder*, Westinghouse Electric Corporation, Buffalo, N. Y.

Industrial Communication and Paging. *W. S. Watkins*, The Ohio Rubber Company, Willoughby, Ohio

Electrostatic Casualties in the Rubber and Plastics Industries. *Robin Beach*, Engineers Associated, Brooklyn, N. Y.

The New Safety Code for Mills and Calenders in the Rubber Industry. *E. W. Beck*, United States Rubber Company, New York, N. Y.

Arrangements Completed for Electronic Components Conference

Final arrangements have been completed for the Conference on Improved Quality Electronic Components to be held in Washington, D. C., May 9–11, 1950. Sponsors of the conference are the AIEE, the Institute of Radio Engineers, and the Radio Manufacturers Association, to be actively assisted by the National Bureau of Standards and the United States Department of Defense. A tentative program for the conference, indicating session subjects and authors, was included in the April issue (*p 368*).

Headquarters hotel for the conference is the Roger Smith, and the sessions will be held in the nearby Department of Interior Auditorium. The fee for advance registration is $2, while registration at the door will cost $3. Also, a consolidated booklet of papers and discussion at the conference is scheduled for early publication at $2.50 per copy. The mailed registration card, properly completed, together with a check or money order for the advance registration fee and advance orders for the booklet, if desired, should be sent to: Arthur E. Zdobysz, 5510 Parkland Courts S.E., Washington 19, D. C. Checks should be made payable to Mr. Zdobysz.

It is suggested that hotel reservations be made as soon as possible. Blocks of rooms have been reserved at the following hotels: Roger Smith, Raleigh, Hamilton, New Colonial, Ambassador, Lafayette, Lee House, Blackstone, Martinique, and National.

Technical Program Released for Conference on Telemetering

All persons interested in telemetering are invited to attend the special technical Conference on Telemetering which is to be held at the Benjamin Franklin Hotel, Philadelphia, Pa., May 24–26, 1950, as announced in the March issue (*EE, Mar '50, p 267*). The objective of the conference, which is sponsored jointly by the AIEE Joint Subcommittee on Telemetering and the National Telemetering Forum, is to bring together two branches of the telemetering art, the "point-to-point" and the "mobile."

An interesting inspection trip through the Research and Development Laboratories of the Franklin Institute is scheduled for Wednesday morning, May 24. Those who file clearance with the Security Officer, Inspector of Naval Material, 17 Brief Avenue, Upper Darby, Pa., will be given an added tour of the Restricted Project Work of the institute. Telemetering system exhibits also will be available. Local transportation will be provided from the hotel to the Franklin Institute.

The registration fee for the Conference on Telemetering will be $3.50 for advance registration and $4 for those who register at the time of the conference. All papers presented on the program, together with related discussion, are scheduled for publication in booklet form to be priced at $3.50 per copy. Copies may be ordered at the conference. However, advance orders are requested.

Advance registration and advance orders for the booklet should be sent to S. E. Moore, Philadelphia Electric Company, 900 Sansom Street, Philadelphia 5, Pa. Make checks payable to: AIEE-NTF, M. J. A. Dugan, Treasurer. Reservations should be made early with the Benjamin Franklin Hotel.

The Franklin Institute in Philadelphia, Pa., which will be the subject of an interesting inspection trip on Wednesday, May 24, of the Technical Conference on Telemetering

Program

AIEE/NTF Conference on Telemetering

Wednesday, May 24

9:00 a.m. Registration

10:00 a.m. Inspection trip to Franklin Institute

2:00 p.m. General Features of Telemetering

Call to order by W. J. Mayo-Wells, Conference Chairman

Introduction of W. F. Henn, Chairman of AIEE Philadelphia Section

Address of Welcome by W. F. Henn

Turning over of chairmanship by W. J. Mayo-Wells to G. M. Thynell, Vice-Chairman of conference

Historical Notes on Point-to-Point Telemetering. *P. A. Borden*, The Bristol Company

Historical Sketch of Mobile Telemetering. *W. J. Mayo-Wells*, Applied Physics Laboratory, The Johns Hopkins University

Telemetering Terminology. *J. F. Brinster*, Applied Science Corporation

Understanding Accuracy. *H. C. Thomas*, *E. E. Lynch*, General Electric Company

Functional Analysis of Telemetering Systems. *W. H. Burnham*, General Electric Company

Thursday, May 25

9:00 a.m. Telemetering Systems

C. H. Hoeppner, Chairman

Telemetering in the Natural Gas Industry. *W. E. Rufleth*, The Bristol Company

Telemetering at the Naval Research Laboratories. *K. M. Uglow*, Rocket Sonde Research Branch, Naval Research Laboratories

Telemetering in a Large Interconnected Power System. *C. K. Duff*, Hydro-Electric Power Commission of Ontario

APL FM/FM System. *J. W. Hamblen*, Applied Physics Laboratory, The Johns Hopkins University

A High-Speed System of Telemetering, Using Frequency as a Translating Means. *W. E. Phillips*, Leeds and Northrup Company

2:00 p.m. Telemetering Systems

P. A. Borden, Chairman

Applications of Rectified Current to Telemetering on a 2-Conductor Circuit. *F. F. Uehling*, Consulting Engineer

Telemeter Computing Systems for Industrial Process Functions. *A. J. Hornfeck*, Bailey Meter Company

An Electromechanical Transducer. *H. W. Kretsch*, *J. F. Engelberger*, Manning, Maxwell and Moore

Specialized Problems in Rocket Telemetering. *Marcus O'Day*, Air Materiel Command

Telemetering at Glenn L. Martin. *J. M. Pearce*, Glenn L. Martin Company

Friday, May 26

9:00 a.m. Telemetering Systems and Pickups

W. D. Tietjens, Chairman

Radiosonde Telemetering. *L. E. Wood*, Friez Division, Bendix Aviation Company

Special Transducers for Basic Parameter Electric Conversions. *C. A. Dyer*, Minneapolis-Honeywell Regulator Company

Unbonded Strain Gauge Telemetering Pickups. *C. E. White*, Stratham Laboratories, Inc.

Temperature Pickups and Their Use With Magnetic Amplifiers. *V. C. Westcott*, Trans-Sonics Inc.

Solar Pickup. *L. M. Biberman*, Naval Ordnance Testing Station, Inyokern

2:00 p.m. Data Presentation and Other Topics

A. J. Hornfeck, Chairman

The Metrotype System of Digital Recording and Telemetering. *G. E. Foster*, Metrotype Corporation

Aeronautical Telemetering. *M. V. Kiebert, Jr.*, Raymond Rosen Engineering Products, Inc.

Sweep Balance Telemetering. *G. Keinath*, Consulting Engineer

A Semiautomatic Method of Reducing Telemetered Oscillogram Data. *J. Weaver*, Telecomputing Corporation

The Present Status of Data Reduction Requirements. *B. S. Benson*, Douglas Aircraft Company

Performance Results of the Ampex Magnetic Tape Recorder Recording Frequency Modulation and Pulse Width Telemetering Data. *M. J. Stolaroff*, Ampex Electric Corporation

Increased Prestige Sought for Fall General Meetings

At its meeting on February 2 and 3, 1950, the AIEE Board of Directors expressed regret that the Fall General Meeting of the Institute has not thus far been accepted as equivalent to the Winter and Summer General Meetings, and discussed possible solutions of the difficulty.

When the Fall General Meeting was introduced, it was intended as annual Institute meeting for the members in the middle area of the United States, many of whom cannot attend the other meetings. It was hoped, also, to relieve the pressure on the technical programs of the Winter and Summer General Meetings. Thus far, however, there has been difficulty in securing adequate numbers of papers for the Fall General Meeting, and the programs of the other large meetings have continued to be heavier than desirable. For example, in the year 1947–48, the Fall Meeting presented 60 papers while the Winter Meeting had a total of 217 papers. For the year 1948–49, the Fall General Meeting program had increased to 125 papers, but the Winter Meeting program also saw an increase, to 233 papers. At the latest of the Fall Meetings, the 1949 Fall General Meeting, 125 papers again were presented, while the program for the January 1950 Winter General Meeting increased still further, to an unprecedented 243 conference and technical program papers. However, it is realized that the Fall General Meeting is a new activity and so needs stimulation if it is to attain the prestige of the other general meetings of the Institute.

The 1950 Fall General Meeting is scheduled for October 23–27 in Oklahoma City, Okla. With July 25 as the final date for submitting papers, there is still time to make this a successful and worth-while addition to the Institute's annual meetings.

Former Subsection Becomes Northeastern Michigan Section

On March 15, 1950, the first regular meeting of a new AIEE Section, the Northeastern Michigan Section, was held at Frankenmuth, Mich., with a special Ladies' Night program. Present at the ceremonies were 208 members and their wives who also heard a lecture on "Modern Home Design."

The group was originally organized in 1945 as the Saginaw Valley Subsection of the Michigan Section, including in its territory the cities of Flint, Owosso, Saginaw, Midland, and Bay City, Mich. After recommendation by the Sections Committee and approval by the Board of Directors of the change of status, the Michigan Section on February 21, 1950, appointed the elected officers of the Saginaw Valley Subsection to act as temporary officers and directors of the Northeastern Michigan Section until the next regular election. The Chairman is E. L. Holmgren, Kuhlman Electric Company, Bay City, Mich. T. O. Morgan, General Motors Corporation, Buick Motor Division, Flint, Mich., is Vice-Chairman, and F. H. Justin, Dow Chemical Company, Midland, Mich., is Secretary-Treasurer.

The new Section has 100 Institute members and 105 local members.

AIEE Approves Recommendations of London Engineering Meeting

The Conference of Representatives From the Engineering Societies of Western Europe and the United States of America was resumed, after a year's adjournment, in London, England, September 19–23, 1949. Several recommendations were adopted by the conference and referred to the participating societies for their consideration.

Among those recommendations which were approved by the AIEE Board of Directors at their February 1950 meeting were: that participating societies advise foreign students about trips through their territories; that close co-operation be effected between the societies and UNESCO; and that abstracting services in the engineering field be co-ordinated more closely and a working party be set up for this purpose. It was proposed that the next meeting of the conference be held in Holland in the autumn of 1951.

The Institute was represented at the conference by AIEE Secretary H. H. Henline.

President and Mrs. Fairman Visit AIEE Georgia Section

AIEE President and Mrs. James F. Fairman were guests of the Georgia Section at dinner on March 1, 1950, in the Georgia Institute of Technology's Brittain Hall. Approximately 104 members and wives were in attendance to hear Mr. Fairman speak on the statistical analysis of the recent AIEE poll on engineering unification, and to hear him discuss the current poll. W. P. Hammond, Vice-President in charge of engineering, Georgia Power Company, acted as toastmaster, and L. M. Shadgett, Vice-President and Athens Division Manager of the Georgia Power Company, a former associate of Mr. Fairmans', introduced Mr. Fairman.

Prior to the principal address by Mr. Fairman, members and their guests were entertained by a short program of legerdemain, after which the Fellows of the Georgia Section were enumerated and those present visibly recognized. Among those present were H. E. Bussey, Cherry L. Emerson, John M. Flanigen, H. G. Harvey, and John E. Mellett.

The Georgia Section took the opportunity of Mr. Fairman's visit to present its first Past Chairman's key to Robert O. Loomis, Georgia Section Chairman in 1948–1949. Presentation was made in the name of the section by Otis O. Rae.

Preceding the evening activities, Mrs. Fairman was the luncheon guest of the wives of the Section members, while Mr. Fairman and the Section officers were the guest of Georgia Section Member C. B. McManus, President of the Southern Company and also of the Georgia Power Company.

F. O. McMillan Addresses Richland Section Meeting

With "Engineering Co-operation" as his topic, Professor F. O. McMillan, Head of the Electrical Engineering Department at Oregon State College, was the main speaker at the dinner meeting held by the AIEE Richland (Wash.) Section on March 10, 1950. Professor McMillan was introduced by Dean F. Ellis Johnson, General Electric Company, Nucleonics Department Educational Director. Also, R. B. Crow, Secretary-Treasurer of the Richland Section, reported his recent trip to the 1950 AIEE Winter General Meeting in New York as a member of the Nominating Committee from District 9.

In his address, Professor McMillan traced the development of the engineering technical and professional societies in the United States from the formation of the American Society of Civil Engineers in 1852 to the present date (the AIEE was formed in 1884), and he stressed the value of the close work between the several engineering groups which has resulted in the world-wide renown and acclamation enjoyed by the American engineer and his accomplishments.

Professor McMillan described the efforts of Professor Charles F. Scott, President of AIEE in 1902–03, which resulted in the

Shown at a dinner held during AIEE President Fairman's recent visit to the Georgia Section are, left to right, W. P. Hammond, toastmaster for the occasion; Mr. Fairman; L. M. Shadgett, who introduced Mr. Fairman; and E. S. Lammers, Jr., Georgia Section Chairman

Attending the AIEE Richland Section dinner meeting on March 10, left to right: H. R. Hughes; Dean F. Ellis Johnson, who introduced the evening's speaker; F. J. Mollerus; W. J. Dowis; Professor F. O. McMillan, main speaker at the meeting; R. B. Crow; O. Mageehon; L. C. Ford. Messrs. Dowis, Mollerus, and Crow are officers and Messrs. Hughes, Mageehon, and Ford are members of the Executive Committee of the Section

Andrew Carnegie gift of $1,500,000 in March of 1904 to construct the Engineering Societies Building and Library in New York. The speaker also detailed the work in which he is currently engaged as the AIEE representative on the Inter-Society Committee studying ways and means of improving the operation of the college student engineering chapters.

Throughout his discussion, Professor McMillan emphasized the fact that engineers, as a group, owed a great deal to their communities for providing the engineering opportunities. Hence, the engineer should take a more active part in community affairs which are not purely of an engineering nature. He also described the engineering societies' thinking and planning in professional activities which are moving toward the formation of an over-all society for engineers.

South Carolina Student Branch Sponsors Meeting of Subsection

On March 13, 1950, the AIEE Student Branch at the University of South Carolina, Columbia, sponsored a meeting of the Columbia Subsection. Five student papers were presented at the meeting.

Chosen best paper of the evening by judges W. H. Kendrick, Vice-President of the South Carolina Electric and Gas Company; Herbert Eidson, Chief Engineer of radio station *WIS;* and Oren Long, engineer for the Southern Bell Telephone and Telegraph Company; was "Artificial Transmission Line Demonstration," by R. A. Marelli. Mr. Marelli's paper also was presented at the Southeastern Student District Meeting at the Georgia Institute of Technology, April 13–15.

George Washington Branch Visits Generating Station

Twenty members of the AIEE George Washington University Branch, Washington, D. C., took advantage of the opportunity on March 8, 1950, to make a field trip to the Potomac Electric Power Company's new Potomac River generating station.

The 3-hour inspection tour of Washington's newest power plant included observation of the plant's "smoke cleaning system," explanation and demonstration of the control station and main control room operation, and a squint into the 3,000-degree flame that generates steam for the company's newest $1^{1}/_{2}$-million-dollar 80,000-kw turbogenerator. The George Washington engineers also examined the ordinarily inaccessible parts of the plant's number *2* turbine which is now being assembled.

COMMITTEE ACTIVITIES

Editor's Note: This department has been created for the convenience of the various AIEE technical committees and will include brief news reports of committee activities. Items for this department, which should be as short as possible, should be forwarded to R. S. Gardner at AIEE Headquarters, 33 West 39th Street, New York 18, N. Y.

Communication Group

Committee on Telegraph Systems. (*I. S. Coggeshall, Chairman; J. A. Duncan, Jr., Vice-Chairman; E. C. Chamberlain, Secretary.*) This committee recently held a meeting to discuss the scope, obtain opinions from committee members as to appropriate subjects for future papers, and investigate the possibility of timely papers for general and District meetings. Consequently, discussion centered on subjects which it was believed had not been adequately covered in Institute publications and which might offer fertile ground for investigation, such as telegraph terminal equipment, international standardization, facsimile, station selectors, and modulation.

During the discussion it was mentioned that any papers presented should separate telegraph equipment from various media of communication, as the latter would more logically fall under other communication committees. However, it was pointed out that this separation has caused a lack of information on system planning. Information on terminal equipment and communication channels would be of considerably more value if it could be combined into descriptions of entire systems. It was agreed there might be considerable advantage in joint meetings between this committee and the closely allied committees to discuss this possibility.

General Applications Group

Committee on Land Transportation. (*H. F. Brown, Chairman; L. W. Birch, Vice-Chairman; R. L. Kimball, Secretary.*) This committee has been giving considerable thought to subjects for suitable technical papers, endeavoring to keep in touch with all new developments in its field. Recently one of the important papers presented covered the application of a mercury-arc rectifier for use on multiple-unit cars and other forms of motive power on a-c railways and discussed the performance of a car equipped with such apparatus on an a-c electrified railroad. This important development marks a new milepost in electric traction and would seem to offer new possibilities in the application of electric power to railroad operation.

It was thought that papers dealing with diesel-electric equipments and problems would be suitable for a western meeting, such as the Summer and Pacific General Meeting. The committee plans to develop papers to constitute a multiple-unit car session and a light traction session at a future meeting.

The chairman has urged greater coordination between the activities of this committee and the Electric Section, Engineering Division of the Association of American Railroads.

The Standards Committee has accepted the subcommittee's revision of Electric Control Apparatus Standards.

Last November a questionnaire on heavy traction electrification was mailed to 12 operating companies, including steam railroads, metropolitan districts, and an electrified interurban road, which seemed to cover the field from the standpoint of various types of electrification. Eventually questionnaires will be sent to foreign countries.

Industry Group

Committee on Electric Heating. (*G. W. Scott, Jr., Chairman; J. C. Handy, Vice-Chairman; L. M. Duryee, Secretary.*) This committee held a meeting in January and reviewed the progress of its activities. A proposal was made and accepted to drop electric furnace work, as in almost every manufacturing plant electric furnace work has become metallurgical rather than electrical, and electrical problems of electric furnace design and manufacture have become well standardized. On the other hand, it was proposed that psychological effects of infrared heat need more study since data on this phase of infrared are lacking. The subject was referred to the Subcommittee on Infrared Radiation for future work, in addition to the subject of fruit ripening and flower blossom control.

Subcommittee on Induction and Dielectric Heating (*W. C. Rudd, Chairman*). This subcommittee has completed its work on definitions which have been cleared with the Institute of Radio Engineers, and is now starting a study of "Equipment Standards." It has also continued work on radio interference with the Federal Communications Commission.

Subcommittee on Resistance Heating and Electric Furnaces (*L. P. Hynes, Chairman*). This subcommittee has been able to have the notation of watts-density included in new catalogues of the major manufacturers of electric heating equipment, which should be a help to designers and users of these devices.

Subcommittee on Standards of Committee on Industrial Control. (*J. J. O'Connor, Chairman.*) A project has been started to study graphical symbols for use in connection diagrams. American Standards Association Standard *Z32.12,* which has been sponsored by AIEE, has now been in force for several years, and the standard symbols have found wide acceptance by both manufacturers and users. While these standard symbols have in general worked out very well, certain criticisms have been raised on the part of some user groups. They are primarily based on the claim that the standard symbols do not represent certain mechanical contact functions, such as on limit switches, with sufficient clarity.

Universal acceptance of standard symbols is of paramount importance to manufacturers and users of control equipment alike. From the users' point of view it is very desirable to have diagrams drawn by various organizations use uniform symbols to facilitate easy interpretation of such diagrams. Owing to the importance of symbols, the Industrial Control Committee will study the adequacy of the present ASA standard symbols and, if it should appear desirable, submit proposals for revision.

Any material which any member of the Institute may wish to submit for consideration will be appreciated.

Power Group

Committee on Insulated Conductors. (*Herman Halperin, Chairman; V. A. Sheals, Vice-Chairman; C. T. Hatcher, Secretary.*) An important point in the creation of this new committee was to provide an ample avenue in the AIEE for advances in the art in all directions relating to developments, design, installation, and operation for insulated wires and cables. Some idea of the ramifications of the committee's activities are indicated by the names of the subcommittees, namely, Standards and Publications, Cable Characteristics, Conductors, Insulations, Sheaths and Coverings, Cable Supply Systems, Utilization Wiring Systems, Special-Purpose Cable, Accessories, Structures, and Tests and Measurements.

The committee has a large number of projects under way. In addition to meetings of the Administration Subcommittee, there are held two combination meetings of the committee and its subcommittees during each administrative year. The next meeting will be on May 22 and 23 at the Hotel Sheraton, Chicago, Ill. There are almost 100 members and special members of the committee and so far the average attendance at meetings has been over 50.

In the papers sponsored by the committee and presented at recent meetings, the main subjects were design of joints and potheads and thermal problems for installed cables. Several papers related to the insulation of different types of cable. Papers are in preparation regarding conduits and manhole construction, lead-alloy sheathing, medium-pressure gas-filled cables, and so forth, for presentation at later meetings.

During the past few months much time has been spent in preparing revised definitions for wires and cables in connection with the revision of the "American Standards Definitions of Electrical Terms" (American Standards Association Standard *C-42*).

Committee on Relays. (*E. L. Michelson, Chairman; A. J. McConnell, Vice-Chairman; J. R. Linders, Secretary.*) During the present administrative year, the Committee on Relays initiated four new projects and four new Project Committees have been set up.

Remote Tripping Schemes (*H. P. Sleeper, Chairman*). It is the objective of this Project Committee to collect all possible information on the engineering features of all types of existing remote tripping schemes and a statement of operating experience with each. It is hoped that an analysis of these data will enable this committee to ascertain what primary difficulties are being experienced with this type of relay protection and determine thereby the direction in which further research is required to eliminate fundamental difficulties which have been experienced so that an economic and satisfactory basic engineering solution may be attained.

Effective Vibration and Shock on Relays (*C. E. Asbury, Chairman*). The scope of this committee will be limited to relays used on electric power systems and industrial applications. It is expected that the industry will be surveyed in order to obtain past experience concerning difficulties encountered with vibration and shock. It is hoped to obtain measurements of vibration and shock in a number of power plants and substations, and if possible a certain amount of testing will be done in the laboratory on various types of panels and relay mountings to determine how each is affected by vibration and shock.

Test Methods and Equipment (*G. E. Dana, Chairman*). The principal purpose of this project is to study various testing methods being used in the industry for the purpose of publishing information and possibly recommendations on desirable methods.

Pilot Wires (*H. F. Lindemuth, Chairman*). Several years ago the Committee on Relays published a report on operating experience with pilot wires. The purpose of the present Project Committee is to bring the published information in this field up to date. This committee also expects to gather information relative to new or unusual pilot-wire relaying schemes.

Science and Electronics Group

Subcommittee on Applied Mathematics of Committee on Basic Sciences. At a recent meeting it was decided that it would be highly desirable to bring engineers and mathematicians closer together. The means suggested to attain this end was to have engineers submit problems involving the use of mathematics to this subcommittee, which would, in turn, translate these engineering problems into mathematical language and submit them to the mathematicians who are being invited to serve on this subcommittee. A selected number of problems solved will be discussed at a conference on mathematics, sponsored by the subcommittee and held at one of the AIEE meetings. This activity is not a "consulting service" but is rather a method of contact for the AIEE membership with the field of mathematics. Its sole object is to encourage engineers to use mathematics more freely and to enlist the interest of mathematicians in the application of their science to the problems of the engineer. It is hoped that in time this effort will result in a closer relationship between engineering and mathematics to the end that few engineers would hesitate to use mathematics in solving their problems and more mathematicians would appreciate the usefulness of their science in technology.

AIEE PERSONALITIES.....

N. E. Funk (A '07, F '34, Member for Life), Director and Executive Vice-President, Philadelphia (Pa.) Electric Company, has retired after more than 40 years of service with the company. Mr. Funk is a Past President of the Institute (1943–44) and also a former Director of the Institute (1934–38). He was born in Bloomsburg, Pa., on November 4, 1883, and received an Electrical Engineering degree from Lehigh University in 1905. Prior to his association with the Philadelphia Electric Company in 1907, Mr. Funk was an Assistant Professor at the Georgia School of Technology and was also with the Westinghouse Electric and Manufacturing Company and the New York Central Railroad. His association with the Philadelphia Electric Company has been marked with consistent advancement from his first job as Assistant Foreman of Station Construction. A few of the many Institute committees on which Mr. Funk has served are: Power Generation; Legislation Affecting the Engineering Profession; Edison Medal; John Fritz Medal Board of Award; and Members-for-Life Fund. Mr. Funk has also served on many other engineering societies such as The American Society of Mechanical Engineers, the Association of Edison Illuminating Companies, the American Society for Testing Materials, and the Edison Electric Institute. He is also a member of the Pennsylvania Electric Association, the Franklin Institute, the Engineers Club of Philadelphia (Past President), and Sigma Xi. **R. G. Rincliffe** (A '42) succeeds Mr. Funk as Director and Vice-President of the Philadelphia Electric Company. Mr. Rincliffe joined the company in 1923 as an engineering assistant

N. E. Funk

and rose to the position of Vice-President in charge of electric operations prior to his present appointment. He is a member of many industrial associations including the Electrical Association of Philadelphia, the American Gas Association, and the Pennsylvania Gas Association. Mr. Rincliffe is also a member of The American Society of Mechanical Engineers and the Franklin Institute.

E. L. Moreland (A '11, F '21, Member for Life), Executive Vice-President, Massachusetts Institute of Technology, Cambridge, and **R. G. Hudson** (A '10, F '41, Member for Life), Professor, Department of Electrical Engineering, Massachusetts Institute of Technology, have retired. Dr. Moreland was born in Lexington, Va., on July 1, 1885, and was graduated from the Johns Hopkins University with a Bachelor of Arts degree in 1905 and received a Master of Arts degree from the Massachusetts Institute of Technology in 1908. His engineering work consisted mainly of the development of steam and hydroelectric plants and problems of power transmission and utilization in the public utility field and for large industrial plants. He has been a member of the firm of Jackson and Moreland, Boston, Mass., since 1919. During World War I, Dr. Moreland served as captain and later major of engineers in the American Expeditionary Forces. For his services in World War II the War Department awarded him the Medal of Freedom and President Truman bestowed upon him the Medal for Merit. He has had several books and technical papers published and has been active in many engineering societies, particularly the Engineers' Council for Professional Development and its Committee on Engineering Education. Dr. Moreland has served the Institute on many committees and is a former Chairman of the Boston Section. R. G. Hudson was born in Lawrence, Mass., on June 7, 1885, and received the degree of Bachelor of Science in electrical engineering in 1907. He has been a member of the department of electrical engineering at the institute since 1907 and has been in charge of the course in general science and general engineering since 1932. Mr. Hudson, in addition to his teaching duties, has carried on an extensive practice as consulting engineer, including Director of Research for the Electric Welding Committee of the Emergency Corporation from 1917 to 1918. Mr. Hudson is well known as an author and among his publications are "The Engineers' Manual," "An Introduction to Electronics," and "American Handbook for Electrical Engineers," of which he was associate editor. He will continue with the Massachusetts Institute of Technology as a lecturer. Mr. Hudson is a member of the American Association for the Advancement of Science and the American Association of University Professors.

William Arthur (A '12, M '17, Member for Life), Manager, Mid-Atlantic Region, Allis-Chalmers Manufacturing Company, Milwaukee, Wis., has retired. Born in Wisbech, Cambridgeshire, England, on November 21, 1880, Mr. Arthur was educated at the Railway Institute, Horwich, Lancashire, England, and at Liverpool (England) University. He was awarded a scholarship by the Union of Lancashire and Chesire Institutes for proficiency in scientific and engineering subjects in 1899 and was also awarded the "Thomason" Scholarship in 1900. Mr. Arthur worked as an electrical engineer for the Lancashire and Yorkshire Railroad, the railway department of the Westinghouse Electric and Manufacturing Company (now the Westinghouse Electric Corporation), East Pittsburgh, Pa., and the Yale and Towne Manufacturing Company, Stamford, Conn., before starting his own manufacturing business at New Haven, Conn., in 1909. He has also worked for various other companies before his association with the Brown-Boveri Electric Corporation, Camden, N. J., which was purchased by the Allis-Chalmers Manufacturing Company in 1931. Mr. Arthur became Manager of the Mid-Atlantic Region in 1948. **A. D. Brown** (A '31, M '45), Manager of the Washington, D. C. office, has been transferred to the Philadelphia, Pa., district office, where he will take the position of Manager.

Donald C. Luce (A '36, F '49), Vice-President in charge of electric operation, Public Service Electric and Gas Company, Newark, N. J., has been elected Vice-President in charge of combined operations and a director of the company. **W. F. Tait** (A '27, M '45), General Manager, Electric Department, succeeds Mr. Luce as Vice-President in charge of electric operation. **E. H. Snyder** (A '27, F '49), Assistant Chief Engineer, Electric Engineering Department, has been appointed General Manager, Electric Department.

Dayton Ulrey (A '34), Manager, Lancaster Engineering Section, Tube Department, Radio Corporation of America, Lancaster, Pa., has retired and will remain associated with the company in a consulting capacity. Dr. Ulrey was born in North Manchester, Ind., on September 19, 1884, and received the degrees of Bachelor of Arts and Master of Arts from Indiana University and the degree of Doctor of Philosophy from Leland Stanford University. Dr. Ulrey instructed in physics at Leland Stanford University and the University of Pittsburgh (Pa.) prior to accepting a Research Physicist position with the Westinghouse Electric and Manufacturing Company (now the Westinghouse Electric Corporation). Dr. Ulrey has been associated with the Radio Corporation of America since 1937.

W. C. White (A '37, M '42), Director of the day divisions, Northeastern University, Boston, Mass., was initiated into the university's Gamma Beta Chapter of Eta Kappa Nu recently. Also initiated were three other Northeastern University faculty members: **R. G. Porter** (A '25, F '44), **H. E. Richards** (A '25, M '36), and **L. F. Cleveland** (A '38, M '46). Mr. White is a member of the Committee on Electronics. Mr. Porter is a member of the Committee on Branches, a Student Branch Counselor, and Chairman of the District 1 Committee on Student Activities. Mr. Cleveland was Secretary of the Boston Section from 1946 to 1949.

H. B. Lee (A '37), Assistant Regional Engineer, Southeast, United States Department of Agriculture, Rural Electrification Administration, has been appointed Regional Construction Engineer for Illinois, Iowa, and Wisconsin. **J. H. Rixse, Jr.** (A '38, M '47), Assistant Regional Engineer, West, has been named Regional Construction Engineer for the Missouri-Arkansas-Louisiana-Oklahoma area. Mr. Rixse is a member of the Substations Committee.

W. H. Sammis (A '20, M '38), President and Director, Ohio Edison Company, Akron, has accepted the chairmanship of the national committee for the School of Engineering, Columbia University. Mr. Sammis is a trustee of the university and is also Chairman of the Board and a Director of the Pennsylvania Power Company and a Director of the Cleveland and Pittsburgh Railroad.

G. F. Maughmer (A '38), Manager, Sales Office, General Electric Company, Los Angeles, Calif., has been appointed to head the new sales district at St. Louis, Mo. Mr. Maughmer has been with the General Electric Company since 1923. He served the Institute as Arizona Section Chairman from 1942 to 1943 and is a member of the Pacific Coast Electrical Association, the Board of Directors of the Merchants and Manufacturers' Association, and the Electric Club, all of Los Angeles.

William Dubilier (A '19, F '25), Technical Director, Cornell-Dubilier Electric Corporation, South Plainfield, N. J., and President, Koldweld Corporation, has been awarded the Chevalier Cross of the French Legion of Honor. The honor comes as an expression of appreciation from France for Mr. Dubilier's contribution to the development of the French and international electrical industry and also for his humanitarian activities.

R. L. Thomas (A '19, F '44), Vice-President, Consolidated Gas Electric Light and Power Company, Baltimore, Md., has been reelected a Vice-President of the company. **A. L. Penniman, Jr.** (A '15, F '43), General Superintendent of the company, also has been elected a Vice-President.

N. M. Levinson (A '42), Field Construction Engineer, Rural Electrification Administration, Region 1, has been appointed to the field engineering staff of the Sprague Electric Company, North Adams, Mass. Mr. Levinson will work on power system apparatus applications.

W. G. Lewis (M '49), Assistant Engineer-in-Charge of Circuit Breaker Sales, Allis-Chalmers Manufacturing Company, Boston, Mass., has been named Assistant to the General Manager of the company's Boston Works. **A. E. Kilgour** (A '39, M '47), Application Engineer, succeeds Mr. Lewis as Assistant Engineer-in-Charge of Circuit Breaker Sales.

OBITUARY • • • • • •

Jacob T. Barron (A '07, M '20, F '27, Member for Life), Vice-President, Combined Operations, and Director, Public Service Electric and Gas Company, Newark, N. J., died March 12, 1950. Mr. Barron was born in Columbia, S. C., on May 22, 1884, and was graduated from the University of South Carolina in 1905 with a Bachelor of Science degree. Following a 2-year period with the Testing Department of the General Electric Company, Schenectady, N. Y., he entered the service of the Public Service Electric and Gas Company in 1907. He started in the testing department of the company and also worked in the construction department prior to his appointment as chief operator of substations and generating stations in the company's Central Division in 1908. Mr. Barron also held the positions of Superintendent, Central Division, General Superintendent of Production, and General Manager, Electric Department, before his promotion to Vice-President in charge of Electric Operations and Director of the company in 1935. In 1948 he was named Vice-President in charge of Combined Operations. Mr. Barron had served the Institute on the following committees: Power Status (1919–24); Joint Committee on Standard Threads for Insulators and Insulator Pins (1919–21); Board of Examiners (1929–30); and Edison Medal Committee (1941–46). He also was a Director of the American Standards Association from 1943 to 1945 and a Director of the Edison Electric Institute.

Howard David Matthews (M '42, F '48), Consulting Engineer, W. M. Chace Company, Detroit, Mich., died February 28, 1950. Born in Carthage, Mo., on May 19, 1893, Mr. Matthews attended Kansas State College and was awarded a Bachelor of Science degree in 1904 and the degree of Electrical Engineer in 1917. From 1904 to 1918 Mr. Matthews was associated with the General Electric Company, Schenectady, N.Y., starting as a test engineer and then working as a design engineer in the Switchboard Engineering Department. He was a Professor of Electrical Design at the Milwaukee (Wis.) School of Engineering from 1918 to 1922. Mr. Matthews worked for the Westinghouse Electric Corporation, East Pittsburgh, Pa., as a design engineer in the Supply Engineering Department from 1922 to 1924 and then transferred to the Mansfield, Ohio, plant to work in the capacity of Section Engineer in the Heating Appliance Engineering Department. He became affiliated with the W. M. Chace Company in 1929, remaining with the company until 1934 when he accepted a managerial position with the General Plate Company, Attleboro, Mass. Following a period of two years in the employ of the Minneapolis-Honeywell Regulator Company, Minneapolis, Minn., from 1938 to 1940, Mr. Matthews returned to the W. M. Chace Company as a Consulting Engineer. He was the holder of many patents on temperature control devices, author of several articles published in technical journals, and a Fellow of the American Institute for the Advancement of Science.

John Franklin Dunn (A '07, M '44, Member for Life), formerly Associate Electrical Engineer, Tennessee Valley Authority, Knoxville, Tenn., died January 12, 1950. Mr. Dunn was born May 17, 1882, in Ocala, Fla., and received the degree of Bachelor of Science from Davidson College. He also studied electrical engineering at the Massachusetts Institute of Technology. Mr. Dunn began his career as a draftsman for the Western Electric Company and the Westinghouse Church Kerr and Company, New York, N. Y., in 1905. In successive years he worked as a draftsman and engineering-designer for Gibbs and Hill, New York, N. Y., and the Electric Bond and Share Company, New York, N. Y. In 1933, he accepted a position as consulting engineer with the Engineer Petroleum Heat and Power Company, New York, N. Y., and in 1936 became associated with the technical section of the Tennessee Valley Authority as an Associate Electrical Engineer.

John Edward Stirling Thorpe (A '06, M '12, Member for Life), President, Nantahala Power and Light Company, Franklin, N. C., died February 24, 1950. Mr. Thorpe was born in Liverpool, England, on January 29, 1883, and was educated at Cornell University, Johns Hopkins University, and the International Correspondence School of Scranton (Pa.). The first ten years of Mr. Thorpe's business career were spent in engineering assignments in Puerto Rico and Canada as well as the United States. In 1915, he joined the Nantahala Power and Light Company, a subsidiary of the Aluminum Company of America, and served in many responsible capacities; he was named President of the company in 1929. Mr. Thorpe was also President of the Southeastern Electric Exchange and a member of the Western Carolina Manufacturers' Association.

Emil Alfred Ekern (A '04, M '15, Member for Life), Senior Electrical Engineer, Fay, Spofford and Thorndike, Boston, Mass., died January 3, 1950. Mr. Ekern was born May 11, 1880, in Pigeon Falls, Wis., and received the degrees of Bachelor of Science in Electrical Engineering from the University of Wisconsin in 1903 and Master of Arts from Cornell University in 1904. After receiving his master's degree, Mr. Ekern instructed in hydraulics, mechanics, and materials of construction at Cornell University, Ithaca, N. Y., for a year. Following several years of hydroelectric design work with various companies, Mr. Ekern became associated with the Stone and Webster Engineering Corporation and served on projects in the southern and mid-western states. During World War II he was placed in charge of electrical engineering projects at Camp Edwards, Buzzards Bay, Mass., and for eight years served in defense work in the United States and Puerto Rico before his affiliation with Fay, Spofford and Thorndike.

Samuel Ferguson (A '02, Member for Life), Chairman of Board, Hartford (Conn.) Electric Light Company, died February 10, 1950. Mr. Ferguson was born in Exeter, N. H., on November 19, 1874, and was graduated from Trinity College in 1896 with the degree of Bachelor of Science. He continued his education at Columbia University, receiving the degrees of Electrical Engineer and Master of Arts in 1899. Mr. Ferguson first became associated with the Hartford Electric Light Company in 1898 and in 1899 accepted a position with the General Electric Company, Schenectady, N. Y., and worked as a research engineer and consultant until 1912, when he returned to the Hartford Electric Light Company as Vice-President. In 1924 he was named President of the company. Mr. Ferguson received the honorary degree of Doctor of Engineering from Rensselaer Polytechnic Institute in 1936. He is a Past President of the Association of Edison Illuminating Companies and served the Institute as Chairman of the Connecticut Section from 1930 to 1931.

Thomas James Creaghead (A '93, Member for Life), retired, died March 4, 1950. Mr. Creaghead was born in Covington, Ky., on February 5, 1867, and received a Bachelor of Science degree in Physics from the University of Cincinnati (Ohio) in 1889. He began his industrial career with the Westinghouse Electric and Manufacturing Company (now the Westinghouse Electric Corporation) in 1889 as Superintendent of Construction and in 1891 was elected Vice-President and General Manager of the newly formed Creaghead Engineering Company. Mr. Creaghead managed the Creaghead Engineering Company until his retirement in 1927. He was one of the founders of the National Association of Manufacturers, a member of Sigma Chi, and a life member of the Cincinnati Engineering Society.

Henry Melvin Bascom (M '19, F '30), Consulting Engineer, Stromberg-Carlson Corporation, Rochester, N. Y., died March 14, 1950. Mr. Bascom was born on February 16, 1883, in Catskill, N. Y., and in 1899 was employed by the Acme Telephone Company, New York, N. Y., as a telephone installer. From 1900 to 1906 he worked as a designer for the Ericsson Telephone Company, New York, N. Y., and from 1906 to 1909 he was with the Engineering Department of the New York and New Jersey Telephone Company. From 1909 to 1930 Mr. Bascom worked for the American Telephone and Telegraph Company as a designer. When the development and research department of the American Telephone and Telegraph Company was merged with Bell Laboratories in 1934, he became local facilities director of the system's development department. In 1940 he became director of switching engineering. Mr. Bascom retired from the Bell System in 1947 and became a consulting engineer for the Stromberg-Carlson Corporation. He was the holder of more than 70 patents on communication equipment, developed individually and with associates, and was a member of the AIEE Communications Committee from 1930 to 1934.

Charles Kilbourne Flanders (A '19, M '20), General Department, American Telephone and Telegraph Company, New York, N. Y., died January 11, 1950. Born in Cambridge, Mass., on August 24, 1888, Mr. Flanders took correspondence courses in Electrical Telephone and Telegraph Engineering prior to his employment by the Plant Department of the New England Telephone and Telegraph Company in 1907. In 1912, he transferred to the Commercial Department of the company and became Commercial Manager of a district comprised of ten exchanges in Maine. During World War I, Mr. Flanders served as a captain in the Signal Corps of the Army of the United States supervising telephone equipment installation and in 1921 became associated with the American Telephone and Telegraph Company.

Harold Wilberforce Price (A '03, M '35, Member for Life), Professor Emeritus of Electrical Engineering, University of Toronto, Ontario, Canada, died on February 14, 1950. Born August 12, 1877, in Brampton, Ontario, Mr. Price was graduated from the University of Toronto with a Bachelor of Science degree in Electrical Engineering and had been with the university in a teaching capacity since 1902. He received the appointment of Professor in 1919. Mr. Price was a member of various committees of the National Research Council and was chairman of its Subcommittee on Definitions of Electrical Quantities for Canada. He served the Institute as Chairman of the Toronto Section and as a member of the following committees: Education (1919–24, 1929–33); General Power Applications (1926–30); Standards (1936–38); Instruments and Measurements (1936–39); and Basic Sciences (1945–46).

Charles Southerland Hallenbeck (A '21, M '36), Office Manager, Long Lines Engineering Department, American Telephone and Telegraph Company, New York, N. Y., died January 2, 1950. Mr. Hallenbeck was born in Plymouth, N. H., on December 23, 1889, and studied electrical engineering at Worcester (Mass.) Polytechnic Institute. He had been with the American Telephone and Telegraph Company since 1911 except for the years 1917 to 1919 when he served in the Signal Corps of the Army of the United States installing communication equipment. Mr. Hallenbeck assumed the position of Office Manager in 1933.

Morton Brown Avery (M '24, Member for Life), retired, died January 26, 1950. Born on January 24, 1884, in Mottville, N. Y., Mr. Avery studied electrical engineering at the Bliss Electrical School, Washington, D. C. From 1907 to 1915 he was in charge of designing and drafting for the Auburn and Syracuse Electric Railroad Company, Auburn, N. Y., and remained with the company until 1919, advancing to the position of chief purchaser. In 1919, Mr. Avery became associated with the Rochester and Syracuse Railroad Company, Inc., Rochester, N. Y. as Assistant Chief Engineer and remained with the company in that capacity until his retirement in 1933.

MEMBERSHIP • • • •

Recommended for Transfer

The Board of Examiners at its meeting of March 16, 1950, recommended the following members for transfer to the grade of membership indicated. Any objections to these transfers should be filed at once with the Secretary of the Institute. A statement of valid reasons for such objections must be furnished and will be treated as confidential.

To Grade of Fellow

Hammond, W. P., vice-pres., Georgia Power Co., Atlanta, Ga.
Jones, E. C., professor; head, elec. engg. dept., West Virginia University, Morgantown, W. Va.
Pye, H. N., chief engr., South Eastern Underwriters Assn., Atlanta, Ga.

3 to grade of Fellow

To Grade of Member

Adcock, H. V., product dev. elec. engr., Line Material Co., Zanesville, Ohio
Bouton, M. N., elec. engr., Wagner Elec. Corp., St. Louis, Mo.
Bradley, E., district engr., Southwestern Bell Telephone Co., Houston, Tex.
Caswell, A. S., chge. switchgear design group, I-T-E Circuit Breaker Co., Philadelphia, Pa.
Combs, G. U., elec. engr., White Eagle div., Socony Vacuum Oil Co., Inc., Augusta, Kans.
DeSoignie, E., asst. mgr., Soc. D'Enterprise Gen De Travaux Engetra, Brussels, Belgium
Dign, G. N., industrial power engr., Atlantic City Electric Co., Pitman, N. J.
Eckel, C. H., sr. engr., Humble Oil & Refining Co., Houston, Tex.
Fiedler, W. E., engr., Western Electric Co., Chicago, Ill.
Furfari, F. A., consulting & application engr., Westinghouse Elec. Corp., Toledo, Ohio
Garthus, I. B., elec. engr., generation dept., Northern States Power Co., Minneapolis, Minn.
Gochnauer, E. L., chief, power & pumping plant maint., U. S. Bureau of Reclamation, Coulee Dam, Wash.
Gronner, A. D., project engr., Liquidometer Corp., Long Island City, N. Y.
Hamilton, E. L., supervisor, elec. dept., Central Nebraska Public Power & Irrigation Dist., Gothenburg, Nebr.
Harding, W. K., elec. engr., Duke Power Co., Charlotte, N. C.
Hermann, F. W., studio engr., Columbia Broadcasting System, Minneapolis, Minn.
Horstman, W. F., design engr., General Elec. Co., York, Pa.
Johansson, S. G., engr., Western Elec. Co., Allentown, Pa.
Kinzer, E. F., industrial engr., Houston Lighting & Power Co., Galveston, Tex.
Kline, C. M., elec. engr., Ajax Elec. Furnace Corp., Philadelphia, Pa.
Lehmberg, M. M., distribution engr., Houston Lighting & Power Co., Houston, Tex.
Ludden, J. H., district plant engr., The Ohio Bell Telephone Co., Columbus, Ohio
Martin, E. J., project technologist, Owens-Corning Fiberglas Corp., Ashton, R. I.
McDonald, W. C., exchange engr., Southwestern Bell Telephone Co., Houston, Tex.
Moore, C. R., aeronautical design evaluation engr., Electrical Civil Aeronautics Adm., Los Angeles, Calif.
Newton, B. G., power system dispatcher, Roane-Anderson Co., Oak Ridge, Tenn.
O'Hanlon, J. R., planning engr., Potomac Elec. Power Co., Washington, D. C.
Park, H. F., engr., Rural Electrification Adm., Washington, D. C.
Parr, V. P., district engr., Southwestern Bell Telephone Co., Houston, Tex.
Phillips, J. D., engr., Mississippi Power & Light Co., Jackson, Miss.
Pope, S. J., chief elec. engr., Kaiser Aluminum & Chemical Corp., Spokane, Wash.
Pyle, K. N., elec. engr., Ebasco International Corp., New York, N. Y.
Riechel, D. A., sr. engr., The Pacific Tel. & Tel. Co., Portland, Oreg.
Roach, J. L., sr. elec. engr., Aluminum Co. of America, Alcoa, Tenn.
Schacht, R. L., genl. mgr., Consumers Public Power District, Columbus, Nebr.
Sechrist, G. H., elec. engg. prof., University of Nebraska, Lincoln, Nebr.
Seibert, C. B., assoc. prof. elec. engg., West Virginia Univ., Morgantown, W. Va.
Theis, H. T., maintenance & facilities supt., Kaiser Metal Products, Inc., Bristol, Pa.
Tolivar, C. A., elec. group engr., Lockheed Aircraft Corp., Burbank, Calif.
Tuma, G., assoc. prof. elec. engg., University of Oklahoma, Norman, Okla.
Walker, R. M., sr. elec. engr., El Paso Electric Co., El Paso, Tex.

41 to grade of Member

Applications for Election

Applications for admission or re-election to Institute membership, in the grades of Fellow and Member, have been received from the following candidates, and any member objecting to election should so notify the Secretary before May 25, 1950, or July 25, 1950, if the applicant resides outside of the United States, Canada, or Mexico.

To Grade of Fellow

Elahi, S. R., P.W.D. Electricity Branch, Lahore, Pakistan
Vogel, W., Univ. of Cologne, Cologne, Germany

2 to grade of Fellow

To Grade of Member

Ballinger, M. H., Borg-Warner Corp., Muncie, Ind.
Barnard, T. H., New England Tel. & Tel. Co., Brighton, Mass.
Bunting, W. R., Northern Elec. Co., Ltd., Montreal, Quebec, Canada
Byrum, G. P., U. S. Naval Ordnance Test Station, Pasadena, Calif.
Campbell, T. L., Toronto Hydro-Elec. System, Toronto, Ontario, Canada
Casey, A. A., The Cleveland Elec. Illuminating Co., Cleveland, Ohio
Chambers, H. J., Toronto Hydro-Elec. System, Toronto, Ontario, Canada
Chapin, F. J., Niagara Mohawk Power Corp., Albany, N. Y.
Christophel, G. H., Auto Specialties Co., Inc., Elkhart, Ind.
Copp, J. H., American Broadcasting Co., New York, N. Y.
Decker, B. L., Natl. Elec. Coil Co., Buffalo, N. Y.
Dougherty, H. P. (re-election), Southwestern Bell Tel. Co., Oklahoma City, Okla.
Evans, A. W., Dept. of Highways & Public Works, Halifax, Nova Scotia, Canada
Falcone, A. J., Consolidated Edison Co. of N. Y., New York, N. Y.
Faraon, A. J., Texas Power & Light Co., Dallas, Tex.
Feaster, W. C., The Potomac Edison Co., Hagerstown, Md.
Flambouriaris, J. D., Natl. Tech. Univ. & Elec. Div., Ministry of Transport, Athens, Greece
Fleming, D. B. (re-election), The Hydro-Elec. Power Comm. of Ontario, Toronto, Ontario, Canada
Grimmer, E. J., Westinghouse Elec. Corp., Sharon, Pa.
Highbee, K. A., The Marston Co., San Diego, Calif.
Hoey, G., Elec. Dept. Municipality, Singapore, Malaya
Hofmann, J. A., III, Egli & Gompf, Inc., Baltimore, Md.
Johnson, H. C., Certain-Teed Products Corp., Dallas, Tex.
Lindon, P. H., Colo. A. & M. College, Ft. Collins, Colo.
Marino, F., Union Terminal Cold Storage, Jersey City, N. J.
Marsh, C. R., Pennsylvania State College, State College, Pa.
Martz, R. H., Chicago Transit Authority, Chicago, Ill.
Maxwell, H. S., General Elec. Co., Schenectady, N. Y.
Maynard, A. L. R., General Elec. Co., Philadelphia, Pa.
McClintic, W. S., General Cable Corp., New York, N. Y.
Mills, R. L., Magnolia Petroleum Co., Dallas, Tex.
Petersen, A. H. (re-election), Columbia Broadcasting System, New York, N. Y.
Pflug, C. E., Nash-Kelvinator Corp., Kenosha, Wis.
Pohnan, F. J., Commonwealth Edison Co., Chicago, Ill.
Pugh, P. S., II, American Gas & Elec. Service Corp., New York, N. Y.
Rebori, M. J., Consolidated Edison Co. of New York, Inc., New York, N. Y.
Robertson, E. J., Toronto Transportation Comm., Toronto, Ontario, Canada
Rodewig, L. F., General Elec. Co., New York, N. Y.
Schneider, S. S., Westinghouse Elec. Corp., E. Pittsburgh, Pa.
Scoggin, V. G., Elec. Power Board, Nashville, Tenn.
Selby, R. C., St. Regis Paper Co., Pensacola, Fla.
Sen, N. K., Associated Elec. Industries (India) Ltd., Calcutta, India
Singer, C. H., Radio Station *WOR*, New York, N. Y.
Smith, E. R., Alvin H. Johnson & Co., Inc., New York, N. Y.
Stretch, R. J., Monroe Elec. Co., Chicago, Ill.
Vajda, J. P., Bell Tel. Labs., Inc., New York, N. Y.
Watts, J. P., Canadian General Elec. Co., Peterboro, Ontario, Canada
Wehr, E. F., Cleveland Elec. Illuminating Co., Cleveland, Ohio

48 to grade of Member

RCA Announces New All-Electronic Color Television Employing Full-Color Tube

A color television picture tube was demonstrated recently in Washington, D. C., by the Radio Corporation of America, as part of its new all-electronic color television system.

The new picture tube, or kinescope, was shown in two direct-view types. The color picture is viewed directly on the face of the tube the same as black-and-white pictures are seen on the majority of television sets already in use. The high-definition color pictures are reproduced all-electronically. The receiver is unencumbered by any mechanical parts or revolving disks. Thus, there is no flicker, no color breakup, and no whir of a disk as characteristic of any system that utilizes a mechanical scanning disk.

The two color receivers in the demonstration used different types of color picture tubes. One employed a single electron gun to "paint" the pictures. The other used three electron guns, each of which had an electron beam geared magnetically to actuate each of the three primary colors on the face of the tube and blend them true to the original scene being telecast.

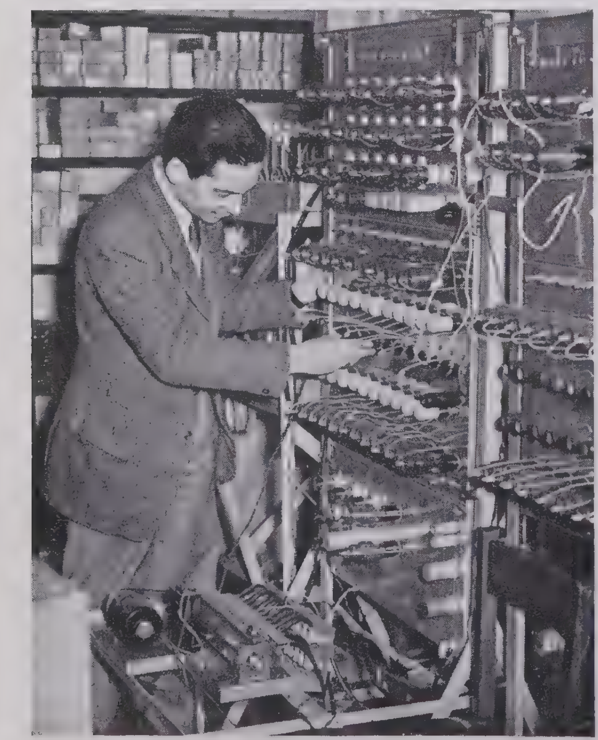
The images are made to appear on the face of the tube by pencil-like beams of electrons that activate fluorescent materials representative of the three primary colors—red, green, and blue. Although the trio of beams all operate simultaneously down the narrow glass neck of the same picture tube, they are controlled so that their actions are masked from interfering with the operation of each other.

The face of each tube is coated on the inside with thousands of dots of color phosphors. The dots are arranged in triangular groups of three, one for each color. The total number of dots per tube, at present, is 351,000, or 117,000 for each color. A metal masking screen, containing 117,000 holes of approximately the same size as the dots of color phosphor, is located behind the tube face. The holes are placed so that they overlap equally each different colored dot of a triangular group.

Electrons pass through the masking screen and activate the color phosphor dots, as the electron gun, or guns, scans the face of the tube, causing the dots to give off visible light. When a video signal representing a certain color passes through the electron gun, that color dot is activated. The amount of colored light given off by each dot varies in accordance with the information supplied from the video signals taken from the air. Images are built up with 525 lines of detail, resulting in a high level of clarity.

The RCA color system operates at both the transmitter and receiver in complete harmony with the existing black-and-white system. Both color and monochrome are capable of existing, or operating, on the same channels, same transmitters, and same receivers. To see the programs in color, the present television receiver in the home can be adapted to use the new color tube, or a new receiver designed to operate with the color tube can be used.

Small Computer to Rival Larger "Brains"



This electronic calculating machine, called SEC, being constructed at Birbeck College Laboratories, London University, will have only 300 tubes as opposed to the thousands required by other electronic "brains," and in addition to performing calculations, it will translate foreign languages. It is planned that the memory capacity of the machine will be ten times greater than that of the larger ones and that SEC will be able to perform within two to three weeks calculations which would take the human brain 100 years to complete

1950 Competition Announced by "Fondation George Montefiore"

L'Institut Electrotechnique Montefiore of Belgium announces the conditions for its international competition held every five years and named for the founder of the institute. There have been two AIEE winners of this competition: Dr. J. B. Whitehead (A '00, F '12, Life Member and Junior Past President) in 1923 and Gabriel Kron (A '30, M '45) in 1935.

The rules for submitting manuscripts and other data follow.

1. A prize (the accumulated interest of Belgian investments at four per cent) is awarded every five years for the best original work presented on scientific advancement and progress in the technical applications of electricity in all fields, excluding commonplace work.

2. The prize bears the name "Fondation George Montefiore."

3. Work prepared during the five years preceding the meeting of the jury of awards will be admitted. Work must be submitted in French or English and may be printed or in manuscript. The jury reserves the right to have them typewritten or printed.

4. The jury consists of ten electrical engineers: five Belgians and five from other countries, under the presidentship of a professor of the Institut Electrotechnique Montefiore, who may be one of the Belgian members. The Belgian members must have a diploma from the institute.

5. By a majority of four-fifths in each of the two sections (foreigners and nationals who must vote separately for this purpose) the prize can be divided.

By the same majority the jury can award one-third of the available prize funds to a person for a capital discovery who has not taken part in the competition or to some work which, without entering completely in the program, shows a new idea capable of having important development in the field of electricity.

6. In the event that the prize is not awarded or if the jury awards only a partial prize, the sum remaining is added to the prize for the following 5-year period.

7. All entries not accompanied by a legible signature and address of the author will be considered anonymous. Such anonymous entries must carry an identification, repeated on the outside and in a hidden fold, on the inside of which must be the author's name, signature, and address written legibly.

8. Twelve copies of each entry must be submitted and may be handwritten or typewritten. They are to be sent postpaid to M. le secrétaire-archiviste de la Fondation George Montefiore, rue Saint-Gilles, 31, Liège, Belgium. The secretary will certify the receipt of entries whose authors have identified themselves.

9. The jury will decide which entries are to be published in the *Bulletin* of the Association of Electrical Engineers put out by the Institut Electrotechnique Montefiore. This incurs no expense on the part of the authors. The association will translate into French such entries in English as are selected for publication.

The amount of the prize for the 1950 competition will be 25,000 francs and all entries must be submitted by December 31, 1950. All entries must carry the following plainly marked at the head of the text, "Travail Soumis au Concours de la Fondation George Montefiore, Session de 1950."

Radio Propagation Field Station Established at Fort Belvoir

A new radio propagation field station which will make continuous measurements of radio waves reflected from the upper atmosphere has been established at Fort Belvoir, Va., by the National Bureau of Standards. The Belvoir Field Station, made possible by the co-operation of the Army's Corps of Engineers and Signal Corps, is one of a system of 14 stations operating under the supervision of the Bureau's Central Radio Propagation Laboratory as part of a world-wide network of over 50 radio observatories.

The station, occupying some ten acres of countryside near the Potomac River, 13 miles south of Washington, consists of four separate buildings designed for ionospheric and geophysical measurements. Equipment at the new field station includes the latest in field intensity recorders, ionospheric recorders, and visually recording magnetographs. The new installation is continuing, on an improved basis, work begun by the National Bureau of Standards more than 20 years ago. Data gathered at the new station will be used in the preparation of predictions three months in advance of the best frequencies for short-wave radio communication as well as warnings of sudden radio disturbances.

The Belvoir Field Station also serves as a training center in the techniques of ionospheric and field-intensity measurements. The station is a testing ground for evaluating the performance of new measuring equipment and procedures proposed for use at all of the Bureau's radio field stations. Special engineering projects are already under way to improve further the ionospheric measuring techniques.

W. F. Little Designated IES Medalist for 1950

William F. Little has been named by the Illuminating Engineering Society to receive the 1950 Gold Medal of the society at ceremonies during the National Technical Conference at Pasadena, Calif., August 21–25, 1950. The Gold Medal, highest honor in the field of illumination, is awarded "for meritorious achievement conspicuously furthering the profession, art or knowledge of illuminating engineering."

Mr. Little, now Engineer in Charge, Photometric Department, Electrical Testing Laboratories, Inc., New York, N. Y., has been identified with the lighting field since 1903 and has been active in the society for more than a quarter century. Best known of his contributions to lighting progress has been his original work in photometry, contributing basic knowledge toward the development of standard specifications for motor vehicles lighting, as well as industrial commercial, motion picture, and natural lighting.

Fulbright Act Authorizes Educational Exchanges

The Fulbright Act (1946) authorizes the Secretary of State to negotiate Executive agreements to use foreign currencies and credits realized through surplus-property sales for the exchange of persons between the United States and other countries for educational purposes.

The use to which the foreign currencies and credits may be put under this authority includes the transportation, tuition, maintenance, and other expenses incidental to scholastic activities of United States citizens going to institutions abroad, the transportation of foreign citizens coming to pursue scholastic activities in this country, and costs incurred by foreign nationals attending American institutions outside the United States.

It is expected that Fulbright programs of international educational exchange will be initiated in the near future with Australia, Egypt, Iran, Turkey, and India since an agreement has been signed recently with each of these countries. Any person wishing to apply for an award as advanced research scholar or visiting lecturer in any one of these countries is encouraged to write the Conference Board of Associated Research Councils Committee on International Exchange of Persons, 2101 Constitution Avenue, Washington 25, D. C. An application form and necessary information will be sent to interested individuals by the Conference Board Committee as each program is inaugurated.

University and college administrators and heads of departments may be interested to know that there may still be time to work out arrangements under the Fulbright program for foreign lecturers to teach in their respective institutions during the academic year 1950–51. More information on this program may also be obtained by writing to the Conference Board.

Recipients of awards to lecturers and research scholars in the field of engineering for the academic year 1949–50 were as follows: Dr. Stephen Crandall, Assistant Professor of Mechanical Engineering at the Massachusetts Institute of Technology, to serve as visiting lecturer in mechanical engineering at the Imperial College of Science and Technology, University of London; Dr. Paul Symonds, Assistant Professor of Engineering at Brown University, Providence, R. I., to do research at the University of Cambridge, England; and Dr. Elmer Tolsted, Jr., Assistant Professor of Mathematics, Pomona College, Claremont, Calif., to serve as visiting lecturer in mathematics at the University College of the Southwest, Exeter, England.

Future Meetings of Other Societies

American Chemical Society. Chicago Section—Sixth National Chemical Exposition. September 5–9, 1950, Chicago Coliseum, Chicago, Ill.

American Electroplaters' Society. Fourth International Electrodeposition Conference. June 12–16, 1950, Statler Hotel, Boston, Mass.

American Society for Quality Control. Fourth National Convention. June 1–2, 1950, Milwaukee, Wis.

American Society of Refrigerating Engineers. 37th Spring Meeting. June 4–7, 1950, Hotel Muehlebach, Kansas City, Mo.

American Society for Testing Materials. 53d Annual Meeting and 9th Exhibit of Testing Apparatus and Equipment. June 26–30, 1950, Atlantic City, N. J.

Armed Forces Communications Association. 1950 Annual Meeting. May 12, 1950, New York, N. Y.; May 13, 1950, Fort Monmouth, N. J.

British Industries Fair. Engineering Section. May 8–19, 1950, Castle Bromwich, Birmingham, England.

Edison Electric Institute. Annual Convention. June 5–7, 1950, Atlantic City, N. J.

Institute of the Aeronautical Sciences. Seventh Annual Personal Aircraft Meeting. May 19–20, 1950, Lassen Hotel, Wichita, Kans. Annual Summer Meeting. July 12–14, 1950, IAS Western Headquarters Building, Los Angeles, Calif.

Instrument Society of America. 1950 Instrument Conference and Exhibit. September 18–22, 1950, Memorial Auditorium, Buffalo, N. Y.

International Conference on Large Electric High-Tension Systems (CIGRE). 13th Session. June 29–July 8, 1950, Paris, France.

Refrigeration Manufacturers of America—Refrigeration Service Engineers Society. 1950 Midwest Refrigeration and Air Conditioning Educational Exhibit and Conference. May 25–28, 1950, New Hotel Jefferson, St. Louis, Mo.

Eta Kappa Nu to Choose Foremost Young Electrical Engineer

For each year, beginning in 1936, Eta Kappa Nu Association, an electrical engineering honor society, has made an award to the most outstanding young electrical engineer. The society is now receiving nominations.

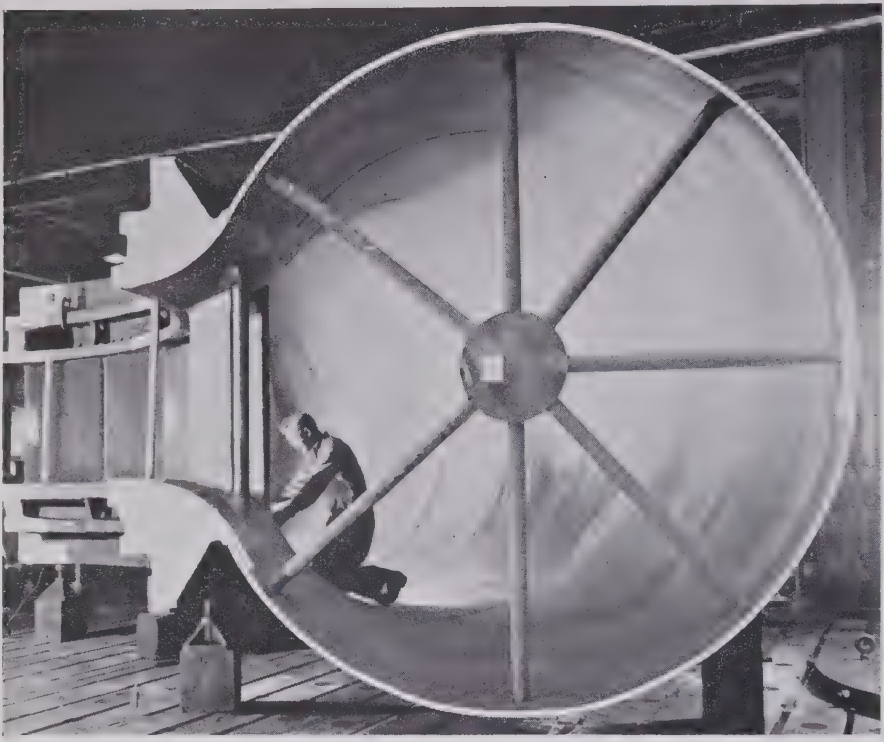
Prerequisite qualifications are

1. Candidate must not have reached age 35 by May 1, 1950.
2. Candidate must have been graduated from a recognized electrical engineering school.
3. Candidate must not have received his Baccalaureate degree in electrical engineering more than ten years prior to May 1, 1950.

Forms for nominations have been distributed to many engineers and executives in the industrial, electrical, manufacturing, communication, central station, and other fields, as well as prominent professors in technical institutions. These people review the records of their young acquaintances to see if they should receive consideration in this competition.

Nomination forms may also be obtained from A. B. Zerby, Executive Secretary, Eta Kappa Nu Association, Post Office Drawer C, Dillsburg, Pa. All nominations should be sent to the secretary and be in his possession by May 1, 1950.

All-Welded Casing for Hydraulic Turbine



The Allis-Chalmers Manufacturing Company is fabricating this plate steel, all-welded spiral casing section for the first unit of three 62,000-horsepower 190-foot-head 128.6-rpm hydraulic turbines for the United States Department of Army, Corps of Engineers, Bull Shoals Development. The section shown has a three-fourths-inch plate thickness. With its integral stay ring and temporary bracing, it weighs over 36,000 pounds. The entire all-welded construction, combined casing and stay ring, is designed in seven convenient radial and circumferential sections. The stay ring portions bolt together. The casing joints are designed for riveted butt strap connections in the field. All the sections are completely shop-assembled for machining and together weigh about 228,000 pounds. Diameter of the casing inlet is 14 feet, 8 inches

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South Bank Exhibition to Tell of British Achievements

The exhibition on the South Bank of the River Thames will be the centerpiece of the Festival of Britain which will be held from May to September in 1951. The exhibition will tell a continuous story throughout the whole of its extent, each pavilion providing a chapter in the story.

The theme is that British achievements in science, technology, and industrial design have resulted from the initiative of the British people in developing the resources of their land and that the future of Britain is well founded on the continuing achievements of her scientists, industrialists, technologists, and designers.

The exhibition will be selective, first, in the topics chosen for the theme and, second, in the choice of exhibits to illustrate the story. A subject qualifying for inclusion must be one in which the British contribution is outstanding—such as an invention like penicillin or the jet engine; an unrivalled British craft like tailoring or fine china; a current national enterprise like the equipment of new schools; achievements in exploration and in scientific discovery; and aspects of the British tradition which have characterized her products. Therefore, many activities and industries in which British achievement is great, but not significantly in advance of other countries, will not be presented.

An industrial exhibit qualifying for inclusion must not only be of high merit on functional, engineering, and aesthetic grounds, but must also be appropriate to illustrate a particular section of the story.

Franklin Institute Develops Projection Magnifier for Print

A device which will permit many individuals with extremely limited vision to read ordinary newspapers, magazines, and books while resting comfortably in their own homes is now in the final testing stage. This new instrument, known as a Projection Magnifier, and developed during several years research at The Franklin Institute Laboratories for Research and Development, Philadelphia, Pa., will magnify normal print to five times ordinary size. Individuals who have a corrected vision of as little as 20/200 have sat at ease before this portable device and read publications with very little manipulation.

Developed under a grant from the W. K. Kellogg Foundation, the Projection Magnifier will undergo tests in actual use for a year, after which time it is expected that it will become commercially available to individuals at less than $75 each. Weighing only a little more than 17 pounds, the magnifier may be used on any table convenient to an electric outlet. When a page is placed on a movable tray at the bottom and a lens lowered against it, an illuminated magnification appears on a ground glass slanted at the correct angle for the reader sitting in a chair.

Little effort is required to handle the device. The screen is wide enough to carry a full newspaper column. For wider pages the lens is controlled by a knob, while the page may be shifted up or down under the lens by means of a lever. The counter-balanced top of the machine is easily raised to turn a page by hand.

World's Most Powerful Synchro-Cyclotron Now in Operation

The world's most powerful synchro-cyclotron, generating 385,000,000 electron volts, is now in operation at Nevis, Irvington-on-Hudson, N. Y., site of Columbia University's new nuclear physics research center.

Major components of the cyclotron are the 2,500-ton magnet, the vacuum and radiofrequency systems, structures concerned with the proton beam, a shielding of 6-foot concrete blocks, and the control system.

Current for the magnet flows through 12 copper coils, each with an outside diameter of 22 feet. The coils are cooled by a flow of 2,000 gallons per minute of special oil which, in turn, is cooled by a maximum flow of 1,000 gallons of water per minute in heat exchangers. The water is pumped from the Hudson River from a point deep enough to assure a flow of water even if the river should freeze over.

An arc source in the middle of the cyclotron chamber generates the hydrogen gas which accelerates the protons at a velocity approaching the speed of light. When the scientists want to produce neutrons or mesons they insert a probe in the path of the protons, and the resulting beam passes out of the chamber to the experimental area north of the instrument.

Around the great magnet is a shielding of concrete blocks measuring 30 feet in some locations, 20 feet in others. The two doors to the chamber are 15-ton blocks, mounted on tracks, which are propelled by attached motors.

New Type of Electric Eye Developed by Bell Labs

An entirely new type of electric eye—much smaller and sturdier than present photoelectric cells—has been invented at Bell Telephone Laboratories.

One of the major advantages of the new electric eye is that it delivers very high power for a photoelectric device, in some cases enough to operate a switch directly without the preliminary amplification usually required.

The new electric eye stemmed from work at the Bell Laboratories on the recently announced Transistor, a simple device capable of performing most of the functions of an ordinary vacuum tube. The new device has

This is the new type of electric eye developed by Bell Telephone Laboratories. Known as the Phototransistor, the new electric eye stemmed from work on the recently announced Transistor. Note the small size in comparison with an ordinary paper clip

been named the Phototransistor and was invented by Dr. John N. Shive of the laboratories' staff. The whole apparatus is housed in a tiny cylinder about as big as a 0.22-calibre rifle cartridge. Like the Transistor, it has no vacuum, no glass envelope, no grid, plate, or hot cathode.

Although the Phototransistor is still in the experimental stage, Bell scientists and engineers expect that, after the necessary development, it may have far-reaching significance in electronics and electrical communication. Consideration is already being given, for example, to using it in a machine under development for toll dialing, a plan whereby a telephone operator directly dials a telephone in a distant city.

The heart of the parent device, the amplifying Transistor, is a tiny chip of germanium, a semiconductor material, against one side of which the points of two hair-thin wires are pressed, hardly two-thousandths of an inch apart. The flow of very small electric currents in one of these wires (the emitter) controls the flow of currents in the other wire (the collector) in such a way as to give signal amplification.

The Phototransistor is similar in operation to the amplifying Transistor, but it is controlled by light rather than by the electric current of the emitter. It also uses a piece of germanium but only a single collector wire. The tip of this wire rests in a small dimple ground into one side of the germanium disk. At this point the germanium disk is only three-thousandths of an inch thick.

Light focused on the opposite, undimpled side of the disk can control the flow of current in the wire, thus making a control device similar in function to a photoelectric cell.

The Phototransistor has a high power output for a photoelectric device and gives good response to a rapidly fluctuating light source. It is particularly sensitive to the wave lengths of light given off by ordinary incandescent light bulbs, and is well suited to operate with these easily available sources with good fidelity. The Phototransistor also is a low-impedance device.

CIGRE Biennial Session Scheduled for Paris

The 13th biennial session of the International Conference on Large Electric High-Tension Systems (CIGRE) is to be held in Paris, France, from June 29 to July 8, 1950. More than 120 technical papers are to be presented at the conference, of which 16 will be of United States authorship.

CIGRE was founded in March of 1921 and operates with the support and assistance of all the large international electrotechnical organizations and includes members from all countries. The object of the conference is to discover and diffuse knowledge of the progress in the technique of large high-voltage electric systems by bringing the most eminent specialists from each country into contact every two years. The conferences are of particular interest to executives and design and operating engineers in both the electric power and electrical manufacturing industries.

Arrangements have been made for a large and representative United States delegation, many of whom will remain for the Fourth World Power Conference to be held in London, England, July 10 to July 15, 1950. Also, the Swedish State Power Board has invited all United States–CIGRE delegates for a tour of electrical installations in Sweden, from June 15 to June 26, 1950, preceding the CIGRE Conference.

The work of the 1950 convention will be divided into four sections. The first section will be concerned with generation, transformation, and rupture of current; the second with construction, insulation, and maintenance of overhead and underground lines; the third with operation, protection, and interconnection of networks; and the fourth with transmission, insulation, and corona effect of extra-high voltages.

The convention will be held at the Fondation Berthelot, 28 bis, rue Saint-Dominique, Paris, France. Further information and registration forms may be obtained from Frederic Attwood, Chairman, United States National Committee of CIGRE, Room 1781, 50 Church Street, New York 7, N. Y.

NBS Detects Low-Frequency Round-the-World Radio Signals

Very-low-frequency radio signals traveling completely around the world have now been detected by the National Bureau of Standards. The signals, transmitted from the Naval Radio Station *NSS* at Annapolis, Md., on a frequency of 18 kc with a power of 350 kw, were received at the NBS radio propagation field station at Sterling, Va., about 50 miles away. Normal delay time for a round-the-world signal was more than a tenth of a second, and maximum signal intensity was observed at sunset.

The round-the-world signals were received, with the aid of a large loop antenna 150 feet high, on a tuned-radio-frequency receiver. A dual-beam oscilloscope was connected ahead of the detector stage in the receiver so that the actual unrectified radio-frequency envelope was displayed on the 5-inch screen along with an 18-kc reference voltage. The delay time of the signals was measured by making a moving film record of the oscilloscope screen.

The test signal transmitted from *NSS* consisted of a series of dots, each dot followed by a quiet period equal in duration to five dots. The test tape was transmitted at normal sending speeds, so that the pulse length of each dot was about 40 milliseconds with a repetition rate of four pulses a second.

C. A. Aall to Deliver Castner Memorial Lecture

Dr. Christian H. Aall, assistant director of the Monsanto Chemical Company's Phosphate Division research department in St. Louis, Mo., has been invited to deliver the Second Castner Memorial Lecture before the Society of Chemical Industry in London, England, and to receive the Castner Gold Medal. He will lecture on the subject of electrothermics and electrothermal processes.

The lectures established to commemorate Hamilton Young Castner, inventor of the mercury-type electrolytic cell for the production of chlorine, are sponsored by Imperial Chemical Industries, of England. Dr. Alexander Fleck, a director of ICI, gave the first of the biannual lectures in 1947.

Dr. Aall, a native of Oslo, Norway, came to the United States in 1946. His technical training was acquired at the University of Grenoble, France.

Monteith Addresses Members of New York Railroad Club

A. C. Monteith, Vice-President in Charge of Engineering, Westinghouse Electric Corporation, Pittsburgh, Pa., addressed the members of the New York Railroad Club recently. The subject of Mr. Monteith's address was "New Horizons for Railroad Motive Power."

One of the motive power developments mentioned by Mr. Monteith was the increased continuous rating of standard electric drive equipment so that the tonnage ratings of freight locomotives are no longer controlled by the capacity of the electric equipment but are controlled by the slipping point of the wheels.

The electrical industry is also co-operating with the roads which prefer to burn coal, as can be illustrated by the new high-pressure high-temperature boiler for the Norfolk and Western Railroad's steam-turbine locomotive. This boiler, built by Babcock and Wilcox, is now in the test stage and will be used on a 4,500-horsepower locomotive to be constructed by the Baldwin Locomotive Works, Eddystone, Pa. This locomotive will burn coal on a stoker-fired grate. The boiler will be of the water-tube type and will operate at 600-pounds pressure, 900 degrees Fahrenheit total steam temperature. The boiler will be forced drafted, permitting the turbine to operate at atmospheric exhaust.

Westinghouse is now completing work on a gas-turbine electric locomotive in their East Pittsburgh (Pa.) Works. This locomotive will be a 4,000-horsepower passenger type, incorporating several novel features. Two 2,000-horsepower turbines are used which burn oil as a fuel. This type of locomotive concentrates a large amount of horsepower in a small space, and is being built by Westinghouse to gain experience in the design and operation of gas turbines in railroad service.

Zator Develops Calculator for Working With Ideas

A calculator for working with ideas instead of numbers, that makes mistakes, but always in the right direction, was exhibited at the meeting of the Association for Computing Machinery at Rutgers University recently. This machine, called the Zator Selector, is used for hunting up ideas and technical information stored in a file. It quickly finds everything you ask for, and when it slips it gives you everything you want and a little more.

The Zator Selector is about the size of a table radio, and it can find facts rapidly from a file which may contain up to a quarter million items in medicine, organic chemistry, physics, or even genealogy.

The secret of the Zator Selector lies in its unusual use of random digit patterns for the ideas. Like the large electronic numerical calculators, the Zator Selector employs a digital technique for working with its non-numerical information. However, it uses a statistical principle of computation rather than the exact rules followed by its larger "brains." It calculates the logical product of two or more ideas in making its selection, instead of performing the more conventional multiplication of two numbers.

EJC Invites Suggestions on National Water Policy

Representing the five national engineering societies, the Water Policy Panel of the Engineers' Joint Council has undertaken the important and timely task of developing a statement on the water resources of the nation, with particular reference to the use and abuse of water supply sources (*EE, Apr '50, p 382*).

The immediate objective of the committee is the production of a statement of professional engineering opinion pertaining to policy and practice in conservation, utilization, and protection of water resources, with especial emphasis on immediate and long-range development of public water supply for domestic, industrial, agricultural, and recreational uses. The deadline set for the panel's recommendations has been moved up to June 1, 1950, and it is suggested that constructive recommendations and suggestions be submitted to Task Committee chairmen as soon as possible.

The eight Task Committees and their respective chairmen are

1. "Domestic and Industrial Water Supply Pollution," Chairman, L. R. Howson.
2. "Flood Control and Water Flow Retardation," Chairman, J. A. Short.
3. "Navigation and Water Transportation," Chairman, Colonel C. H. Brown.
4. "Irrigation," Chairman, S. T. Harding.
5. "Hydroelectric Power," Chairman, Colonel F. W. Sheidenhelm.
6. "Recreation, Fish and Wild Life Aspect of Water Resources," Chairman, M. P. O'Brien.
7. "Basic Water Resources Information," Chairman, G. R. Williams.
8. "Land Drainage," Chairman, Edmund Friedman.

Suggestions and recommendations should be submitted to the Task Committee Chairman, Panel on National Water Policy, Engineers' Joint Council, 25–33 West 39th Street, New York 18, N. Y.

Signal Corps Develops New Milli-Microsecond Pulse Generator

The United States Army Signal Corps has announced an electronic device capable of the generation of pulses of energy existing for only one-thousandth of a microsecond. This development of the Signal Corps Engineering Laboratories, Fort Monmouth, N. J., is expected to provide the basis for many advancements in military electronic equipment, particularly in the field of radio communications.

Similar circuits are currently being embodied in various preliminary experimental models of radio communications equipment ranging from the short-range portable and vehicular equipment up through the trunk microwave radio relay stations. In the video-high-frequency spectrum, presently occupied by tactical radio networks, these narrow-pulse-generating circuits appear to make possible the simplification of wide-frequency-band stabilizing circuits to a point where, in the not too distant future, a signal officer may have a much wider choice of high stable radio-frequency channels incorporated into a single package.

These narrow pulses when used in multichannel telephone terminal equipment are expected to multiply the number of possible channels in time-division multiplex systems. This application is in conjunction with the relatively new form of modulation known as pulse code modulation, first incorporated into communication equipment by the Signal Corps during World War II.

New Allis-Chalmers Engineering Lab. A new 2-room engineering laboratory designed primarily for audio-noise and special temperature tests has been placed in use at the Allis-Chalmers Manufacturing Company, Pittsburgh, Pa. The auxiliary test equipment for this laboratory delivers 1,200 kva over a wide range of voltages which permits standard testing of transformers up to 5,000 kva. The 2-foot thick walls of the new laboratory are constructed of concrete, concrete block and air pockets, fiber glass, and acoustic tile. Its ambient noise level is 27 decibels with the walls absorbing 99.98 per cent of the exterior noise power. In this laboratory the transformers are mounted to simulate actual installation conditions, thereby making it possible to determine the noise level under ideal conditions.

G-E's Educational Thy-Mo-Trol Drive. A new full-wave reversing educational Thy-mo-trol drive, designed to assist in the teaching of electronic motor control and associated circuits, has been announced by the Educational Section of the Apparatus Department, General Electric Company, Schenectady, N. Y. The demonstration equipment consists of seven circuit panels and five instrument panels assembled on a steel frame, mounted vertically on a steel table. The circuit diagrams are molded in white into the front of the dark laminated textolite panels. The actual wiring and all components, excepting the tubes, are behind the panels, with all important circuit points brought to the front of the panel by insulated banana-plug jacks.

New Method of Making Fine Wire. A new method of making fine wire less than one-tenth the thickness of human hair was revealed recently by Dr. Howard T. Francis, supervisor of electrochemistry research at the Armour Research Foundation of the Illinois Institute of Technology. In cooperation with the Naval Ordnance Laboratory, Foundation scientists have produced 0.00015-inch-diameter wire in the laboratory. In the new method wire passes through a chemical bath in which an electric current is flowing. The process polishes away the wire's surface. The new electrochemical method of making extremely fine wire amounts to an eating away of surface metal rather than a mechanical drawing operation.

Whitney Award to R. H. Brown. Robert H. Brown, chief of chemical metallurgy at the Aluminum Company of America's research laboratories in New Kensington, Pa., has been chosen by the National Association of Corrosion Engineers to receive the Whitney Award for 1950 "in recognition of his outstanding contributions to the science of corrosion." The Whitney Award is international in scope and is one of the highest honors in the field of corrosion engineering. Mr. Brown was a pioneer in establishing the theory of cathodic protection and is an authority on the use of aluminum in specific environments. His achievements also include the development of special alclad products and the application of electrochemical methods to the study of aluminum alloys. He is an alumnus of the Drexel Institute of Technology and the Massachusetts Institute of Technology.

IRE Fellow Award to Byrne. John F. Byrne, vice-president and director of Research and Engineering of Airborne Instruments Laboratory, Mineola, N. Y., received the Fellow Award of the Institute of Radio Engineers at its annual banquet at the Hotel Commodore, New York, N. Y., March 8, 1950. The award, among the highest obtainable for IRE members, was accorded Mr. Byrne "For his development of a system of polyphase broadcasting and for effective engineering administration in connection with radar counter-measures during the war." Mr. Byrne received the United States Navy Certificate of Commendation in February 1947 in recognition of his work for the Bureau of Ships, and in 1948 he was the recipient of the Presidential Certificate of Merit. His work in developing a system of polyphase broadcasting, on which part of his honorary award is made, was the forerunner of the omnirange principle.

Kodak Wins "Oscar" for Safety Film. Eastman Kodak Company, Rochester, N. Y., has received one of this year's "Oscars" from the Motion Picture Academy of Arts and Sciences. Kodak's trophy came "for the development and introduction of an improved safety base motion picture film." The company has conducted research on safety film since the early 1920's. The base now developed for safety film is known as triacetate, and the new non-inflammable film is now replacing cellulose nitrate.

ASEE's Engineering Enrollment Data. Unless the percentage of high school graduates entering engineering colleges is increased, there is a strong probability that instead of a large surplus of engineering graduates, which has been prophesied widely, there will soon be fewer engineering graduates available than are needed annually by our national economy. This is the conclusion drawn by a subcommittee of the Manpower Committee of the American Society for Engineering Education from a study of trends in secondary school and engineering college enrollments, and of the statistics on 1949 engineering enrollments and graduations assembled ointly by the society and the United States Office of Education, which are to be published soon by both organizations.

New Method of Making Rain. Dr. Schaefer, weather scientist of the General Electric Research Laboratory, Schenectady, N. Y., recently described a method of helping nature make rain by producing vast "reservoirs" of snow crystals in the sky. Dr. Schaefer said that by overseeding supercooled or below-freezing clouds with large quantities of dry-ice or silver iodide, large areas of snow crystals much too fine to fall might be produced. These reservoirs or snow crystals might remain in the sky indefinitely until new supercooled cloud regions came into contact with the snow area when the tiny snow crystals would act as a seeding agent, causing the new supercooled regions to turn to snow. The additional moisture in the supercooled areas would be sufficient to permit growth of much larger snow crystals or snow flakes, which would have enough size and weight to fall as precipitation.

Miniature Radioactive Isotope Lab. Contamination control in experimenting with certain radioactive isotopes is reduced in cost by the use of a miniature laboratory into which only the gloved hands of the technician protrude. A plywood box and surgical gloves for the technician's hands are sufficient to absorb low-energy radiations from many radio-isotopes. Vinylite resin-base paint is used inside and out because of its chemical-resistant properties. Designed primarily to reduce health hazards and the possibility of cross-contaminating material in radio-isotope experiments, the boxes can also be used with minor alterations for experiments with bacteria, viruses, and poisonous substances.

New Power Plant for St. Louis. United Engineers and Constructors, Inc., Philadelphia, Pa., has been awarded the construction of the first section of the Meramec Power Plant of the Union Electric Company of Missouri. Plans and specifications will be prepared by the engineering staff of the Union Electric Company and all construction will be performed under their general direction. The power plant will be located about eight miles south of St. Louis, Mo., on the west bank of the Mississippi River. The initial installation is to consist of one 110,000-kw high-pressure high-temperature turbogenerator and one boiler, together with all of the required appurtenant facilities.

Soil and Rock Sampling Report. A report presenting the results of the first major research project organized by the Soil Mechanics and Foundations Division of the American Society of Civil Engineers has been issued under the sponsorship of the Engineering Foundation, Harvard University, and the Waterways Experiment Station. The report is the result of the personal efforts of M. Juul Hvorslev, who served the project first as research engineer and later as a member of the Committee on Sampling and Testing. The report is a reference work on subsurface exploration and sampling of soil and rock and gives information and general data on all methods of subsurface exploration and sampling, with a complete bibliography for detailed information on specific topics, as well as a clear and logical delineation of factors influencing the quality of samples, and rules covering the design and operating of equipment for obtaining undisturbed samples.

1949 Technion Yearbook Issued. Featuring an article on "Israel, Teacher of the Middle East," by United States Supreme Court Justice William O. Douglas, volume 8 of the annual "Yearbook" of the American Technion Society was issued recently. The publication, which presents 28 papers and illustrations on topics pertaining to technical, industrial, and educational progress in the United States and Israel, includes contributions from Israel's President, Dr. Chaim Weizmann; Dr. I. I. Rabi, Nobel Prize Laureate in Physics; Philip Sporn (F '30), President, American Gas and Electric Service Corporation, New York, N. Y.; James R. Killian, Jr., President of the Massachusetts Institute of Technology; Bryn J. Hovde, President of the New School for Social Research, New York, N. Y.; and Joseph Weil (F '36), Dean of the School of Engineering, University of Florida. The American Technion Society is a national association founded in 1940 to support Technion (Israel's Institute of Technology) and to advance science and technology in Israel, by funds and technical advice.

Video Mast Atop the Empire State Building. After 18 years, the National Broadcasting Company has given up exclusive rights to use the Empire State Building for radio and television transmission and four stations will make use of a new video mast to be placed atop the building. Besides the National Broadcasting Company, the American Broadcasting Company, the DuMont Network, and *The Daily News* will move their transmitters to the new tower. The new structure will be designed by Dr. Frank G. Kear, of the Washington engineering firm of Kear and Kennedy, with O. B. Hanson, Vice-President and Chief Engineer of the National Broadcasting Company. The entire installation will be designed to handle expected increased wattage and the problems of color television when and if it is introduced. Increased wattage for television awaits the development of new tubes. Preliminary work on the antenna for the new tower, which will be 199 feet high, has started at the Camden, N. J., and Princeton, N. J., laboratories of the Radio Corporation of America.

Plans for Chemical Show in Chicago. The Sixth National Chemical Exposition by the Chicago Section of the American Chemical Society will be held in the Chicago Coliseum September 5 through September 9. Running concurrently with the 118th National Meeting of the American Chemical Society in Chicago, which will have a registration of over 10,000, it is expected that over 50,000 persons will attend the coming exposition. Started in 1940, the National Chemical Exposition has grown steadily in both size and importance. An unusual feature is that it is sponsored by a local section of the American Chemical Society as a means of displaying the importance of chemistry to mankind, and to permit an exchange of ideas between chemists and industries. In addition to over 200 industrial exhibitors, the educational exhibits in the coming exhibition offer a splendid opportunity for showing new products and for the exchange of ideas. Special features, such as the Chemical Trail Blazers, wherein new advances in chemical research or the applications of chemistry are displayed, will again be parts of the show which make it outstanding.

Engineering Bibliographies Available. A selected bibliography of aeronautical engineering subjects listing more than 250 titles grouped under 16 headings, and one of civil engineering subjects listing more than 225 titles grouped under 8 headings, have just been published by the Engineers' Council for Professional Development, New York, N. Y. The titles were selected by more than 100 engineering teachers and professional engineers who co-operated with the Engineers' Council for Professional Development Committee on Professional Training. Most of the books listed are of the college grade and each listing is annotated to indicate the nature and depth of the subject matter. The two bibliographies comprise Sections II and III of a 6-part "Selected Bibliography of Engineering Subjects," which will also contain sections on Mathematics; Mechanics and Physics; Chemical and Industrial Engineering; Electrical and Mechanical Engineering; and Metallurgical and Mining Engineering. The complete bibliography will be available in 1951 but the sections on aeronautical and civil engineering subjects may be obtained now from the Engineers' Council for Professional Development, 29 West 39th Street, New York 18, N. Y., for 25 cents each.

B. F. Goodrich to Use Uranium for Research. Recently the Atomic Energy Commission made available a small quantity of uranium metal for experimental use and the B. F. Goodrich Research Center has obtained a license to purchase a quarter pound of the metal. However, the use to which it will be put has no connection with atomic energy. It will serve to enhance the usefulness of the electron microscope, employed to shadow cast microscope samples showing low contrast. Some of the objects studied with the electron microscope in the rubber industry are so small that it would take a million of them laid end to end to extend a distance of one inch. If these objects are composed of lightweight elements, as is often the case, they show up very dimly on the electron microscope plate. However, if the mounted sample is sprayed with a stream of heavy metal atoms at an oblique angle in a vacuum, a very striking effect is obtained. The particles become coated on one side with a thin film of metal while the areas on the opposite side receive no coating and hence appear as deep shadows on the final photograph. Besides greatly increasing the contrast of the images, this gives an interesting 3-dimensional appearance to the picture, which makes it much easier to identify the particles present.

MIT's Instrumental Analysis Summer Program. Two one-week specialized training programs in instrumental analysis will be offered from July 10–14 and July 17–21 as part of the 1950 summer session at the Massachusetts Institute of Technology. Dr. David N. Hume and Dr. Lockhart B. Rogers, both assistant professors of chemistry at MIT, will conduct the two courses. The facilities of the institute's instrumental analysis laboratory, operated under the direction of Professors Hume and Rogers, will be used extensively. The first week's program, from July 10 to 14, will be devoted to electrical methods of instrumental analysis and will emphasize potentiometry, polarography, conductimetry, amperometric titrations, and applications of self-balancing recording potentiometers. Optical methods of instrumental analysis, including spectrophotometry, colorimetry, fluorimetry, nephelometry, and flame photometry, will be the subject of the second program, July 17 to 21. A number of commercial instruments will be available for operation and evaluation by members of each program. Tuition for each one-week period will be $50. Application forms may be obtained from Professor Gale at Room 3-107, Massachusetts Institute of Technology, Cambridge 39, Mass.

International Chemical Conclave to Be Held. Outstanding chemists and chemical engineers from more than 30 countries will assemble in New York, N. Y., in September 1951, to participate in the largest international chemical conclave in history, in conjunction with the diamond jubilee celebration of the American Chemical Society. This combination of international meetings will be the first of its kind in the United States since 1912.

New Influence-Type Electrostatic Generator. Two recently revealed electrostatic generators of 6 kv and 20 kv are designed to replace cumbersome and short-lived batteries as a high-voltage supply for "snooper-scopes," "sniper-scopes," and similar infrared sighting equipment. The generators were designed by Chatham Electronics Corporation of Newark, N. J., in collaboration with Fort Belvoir, Va. They are extremely compact, weigh only ten pounds, and are powered by a spring motor. Whereas batteries which were formerly used lasted three hours, these units operate indefinitely. One spring winding of the new unit generates for 20 minutes. An interesting point about this type of generator is that, unlike most generators, constant speed results in constant current output rather than constant voltage. Constant voltage output is maintained with a corona discharge regulation tube. This type of tube also eliminates the power wasting and extra power requirements of resistance-type voltage divider regulation.

T. A. Boyd Receives Horning Memorial Award. T. A. Boyd, Research Laboratories Consultant for the General Motors Corporation, recently received the Harry L. Horning Memorial Award from the Society of Automotive Engineers "in recognition of distinguished service in the field of mutual adaptation of fuels and engines." The award honored Mr. Boyd's outstanding contributions during his 30-year study of fuels and engines which has figured prominently and fundamentally in a better technical understanding of the internal combustion engine. The study has benefited not only the motorist, by providing him with improved automotive engines, but also it has made a progressive impact on the economy at large by pointing the way toward more efficient utilization of hydrocarbon fuels. Mr. Boyd collaborated with Charles F. Kettering and the late Thomas Midgley, Jr., in discovery of tetraeythl lead as an antiknock compound for automotive and aviation fuels.

New Public Health Course. The University of Michigan's School of Public Health is offering an in-service training course in Industrial Hygiene and Human Relations for Safety Personnel on June 19, 20, and 21, 1950. The course is designed especially for the benefit of anyone responsible for safety and emphasis will be placed on recognition rather than correction of health exposures for which the advice of industrial hygienists should be utilized. Practical applications will be sought through the inclusion of process engineers and management on the special faculty for the course. Applications for enrollment in the course should be submitted in writing by letter addressed to H. E. Miller, School of Public Health, University of Michigan, Ann Arbor, Mich. The enrollment fee is $5.

LETTERS TO THE EDITOR

INSTITUTE members and subscribers are invited to contribute to these columns expressions of opinion dealing with published articles, technical papers, or other subjects of general professional interest. While endeavoring to publish as many letters as possible, Electrical Engineering reserves the right to publish them in whole or in part or to reject them entirely. Statements in letters are expressly understood to be made by the writers. Publication here in no wise constitutes endorsement or recognition by the AIEE. All letters submitted for publication should be typewritten, double-spaced, not carbon copies. Any illustrations should be submitted in duplicate, one copy an inked drawing without lettering, the other lettered. Captions should be supplied for all illustrations.

Nonlinear Functions

To the Editor:

I wish to point out, in connection with the article "Nonlinear Functions in an Analogue Computer" by McCann, Wilts, and Locanthi (*EE, p 26, Jan '50*), that in the representation of certain mechanical functions by an analogue computer the use of either diode limiters or a function generator to limit a voltage is not always sufficient.

In many instances a position function $x(t)$ is obtained by the integration of a velocity function which is given as an arbitrary voltage $v(t)$. If the position and velocity are those of a physical member which is mechanically limited in position by a physical stop (the control surfaces of a pilotless aircraft, for instance), it is not only necessary that $x(t)$ be limited to the voltages $+x_1$, where x_1 is analogous to the limiting position, but also that $v(t)$ be brought to zero when the position limit is reached.

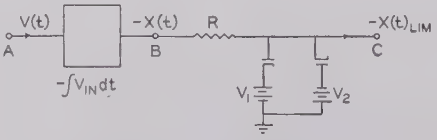


Figure 1. Diode limiter

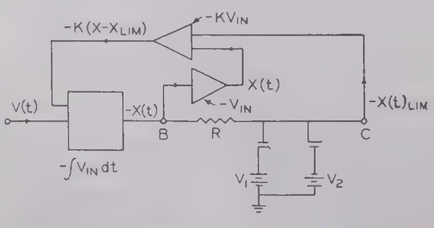


Figure 2. Diode limiter with feedback

In the circuit of Figure 1, if $v(t)$ is, for instance, a constant positive voltage, $-x(t)$ at B will increase linearly with time and $-x(t)_{\lim}$ will be identical with $-x(t)$ up to the limiting voltage as determined by V_2. After the limit is reached, $-x(t)$ will continue to increase, and the difference between $-x(t)$ and $-x(t)_{\lim}$ will appear across resistor R. If the velocity $v(t)$ were now to change sign, $-x(t)_{\lim}$ will not start to decrease until the integrator has removed the voltage drop across R. Physically, however, if the velocity of a moving part changes sign, its position must start to decrease.

The circuit of Figure 2 uses the voltage across R in a feedback loop to drive the input to the integrator almost to zero. The greater the gain in the feedback loop, the more closely will $-x(t)_{\lim}$ hold to the limit voltage V_2, and the smaller will be the voltage across R. As soon as $v(t)$ changes sign, since there is only a small voltage across R to be removed, $-x(t)_{\lim}$ will start to decrease. This corresponds to the true physical situation.

If $v(t)$ is obtained from an acceleration voltage $a(t)$ by integration, it is physically necessary that $a(t)$ be brought to zero when the position is limited. This can be done with another high-gain feedback path driven by the voltage across resistor R.

HOWARD HAMER

(Electronics Engineer, Bell Aircraft Corporation, Buffalo, N. Y.)

Electrostatic or Electromagnetically Induced Field?

To the Editor:

Dr. Slepian (*EE, Feb '50, p 188*) puzzles me. Taking the case of the resultant electric field within the conductor of a transformer winding on open circuit, he insists that the resolution of this (nearly) zero field into an induced field and an (almost) equal and opposite electrostatic field reflects no demonstrable reality.

He then defines potential difference as $\int \mathbf{E} \cdot ds$, provided the (one and only) electric field $\mathbf{E}$ has a potential, so that the result is independent of the integration path, and he defines electromotive force only for closed paths.

Now since $\int \mathbf{E} \cdot ds$ between the terminals of the open-circuited winding does depend on the integration path chosen (for if we follow the path of the winding between terminals we get (nearly) zero), there therefore can be no open-circuit potential difference. Yet I once measured what I was given to understand was the open-circuit potential difference of a transformer manufactured by a competitor of Dr. Slepian's company. I got a definite reading of volts with an electrostatic voltmeter. This "demonstrable reality" could not have been an electromotive force since the circuit was not closed, and it now seems that it was not a potential difference either. What errors the competitors of Dr. Slepian's company do fall into, to be sure!

E. G. CULLWICK (M'33)

(Professor of Electrical Engineering, St. Andrews University, Dundee, Scotland)

To the Editor:

I am sorry that I still puzzle Professor Cullwick. The case of induction in an open-circuited coil of an electric machine was specifically treated in my electrical essay, "Flux Linkage of an Open Circuit" (*EE, Nov '49, pp 984–5*), and in my answer (*EE, Dec '49, pp 1081–2*). There, I pointed out that in the space adjacent to and outside the usual electric machine the varying magnetic field is usually of negligible magnitude, and that therefore the electric field has a potential there. By that I mean, of course, that the integral of the electric force from one point of that region to another point is independent of the path of integration so long as the path remains in this region. It has meaning therefore to speak of the potential difference between two points in this region, and those two points might be the terminals of the machine, if we keep to this understanding that paths of integration are always to remain in this outside region. If we use voltmeters to measure this potential difference we must be careful to keep their leads entirely in this external simply connected region which is free from varying magnetic fields.

This property of having a potential in a limited region was true respectively for each of the two fields external to the boxes of Figure 2 and Figure 3 in my essay, "Electrostatic or Electromagnetically Induced Field" (*EE, Oct '49, p 887*). However, this property of having a potential in a limited region is not enough to characterize the field as necessarily electrostatic, even according to Professor Cullwick's arbitrary definition, for as I read his book, "Fundamentals of Electromagnetism," MacMillan, 1939, he would call the external field of Figure 2 all electrostatic, and that for Figure 3 all electromagnetically induced.

I hope this discussion up to this point takes care of the potential difference between the terminals of an open-circuited transformer. I agree that there is a potential difference there, so long as we limit our means for observing it, to lying outside and near the transformer case. However, this to me is not equivalent to saying that the field is all electrostatic. I would say that that question has no uniquely valid meaning, while Professor Cullwick, as I understand him, would say that before he could make a statement as to the electrostatic character of the field even though it has a potential outside the case, he would have to make sure the transformer case was not insulating, and if it was insulating, then he'd have to pry around inside the case before he would make a commitment.

Now, for the electromotive force of an open-circuited complete transformer winding, I certainly will not integrate the electric field along the winding from one end to the other, and call it the electromotive force. As Professor Cullwick says, I'll only get zero. I define electromotive force only for closed paths of integration. However, if I close my path of integration through the coil by a path outside the case, where the field has a potential, then the integral obtained is independent of where I take my closing path in the external region. Thus I give meaning to the engineer's electromotive force of an open winding when that winding can be closed by a path external to the machine, by defining it as the integral of the electric force around the path so closed. It will of course be the same as the potential difference between the coil terminals, this potential difference being defined over paths lying external (see *EE, Dec '49, p 1082, col 2*).

For a part of a coil which cannot be closed by such an external path (for example a half-turn), I give no interpretation of what an engineer might mean by the induced electromotive force. Actually such an electromotive force never appears in any final design or calculation of the engineer. Professor Cullwick believes that he can define such an electromotive force. This I do not deny, but merely point out his definition is arbitrary, and requires knowledge of all the varying magnetic fields in the universe before he can apply it in any case.

I hope this letter may relieve somewhat the puzzlement which I seem to induce in Professor Cullwick.

J. SLEPIAN (F '27)

(Westinghouse Research Laboratories, East Pittsburgh, Pa.)

NEW BOOKS • • • • •

The following new books are among those recently received at the Engineering Societies Library. Unless otherwise specified, books listed have been presented by the publishers. The Institute assumes no responsibility for statements made in the following summaries, information for which is taken from the prefaces of the books in question.

BEAMA CATALOGUE 1949–50, published for the British Electrical and Allied Manufacturers' Association, 36 and 38 Kingsway, London, W. C. 2, England, by Iliffe and Sons Limited, Dorset House, Stamford Street, London, S. E. 1, England. 852 pages, illustrations, diagrams, tables, $11^3/_4$ by 9 inches, cloth, for private distribution. The comprehensive range of products which members of BEAMA can supply is illustrated and described in this collective catalogue which brings together in a compact and convenient manner information for the overseas buyer on products and services of a great industry. Data are grouped alphabetically by firms in three broad divisions: power plant; industrial equipment; domestic and commercial apparatus and appliances. A short account of the history and work of the BEAMA is also included.

ASTM STANDARDS ON COAL AND COKE. Prepared by ASTM Committee D-5 on Coal and Coke, October 1949. American Society for Testing Materials, 1916 Race Street, Philadelphia 3, Pa. 729 pages, illustrations, diagrams, charts, tables, 9 by 6 inches, paper, $2. This booklet brings together all of the ASTM standards on coke and coal. It gives 28 test methods, specifications, definitions of terms, and numerous proposed methods. Coal sampling, analysis for volatile matter in connection with smoke ordinances, grindability, drop shatter test, tumbler test, screen analysis, size, sieve analysis, cubic foot weight, index of dustiness, and free-swelling are covered for coal and coke.

CHARACTERISTICS OF ELECTRICAL DISCHARGES IN MAGNETIC FIELDS. (National Nuclear Energy Series Division 1—Volume 5.) Edited by A. Guthrie and R. K. Wakerling. McGraw-Hill Book Company, New York, N. Y.; Toronto, Ontario, Canada; London, England, 1949. 376 pages, diagrams, charts, tables, $9^1/_4$ by 6 inches, linen, $3.50. Covering most of the investigations carried out at the University of California Radiation Laboratory, this book considers the subject with main emphasis on discharges in the vapors of uranium compounds. The majority of the papers presented are based on reports written for use within the Manhattan Project. It is hoped that the data included will make an important contribution to the understanding of the theory of gaseous discharges and indicate areas for fruitful investigations.

COMMUNICATION CIRCUIT FUNDAMENTALS FOR RADIO AND COMMUNICATION ENGINEERS. By C. E. Smith. McGraw-Hill Book Company, New York, N. Y.; Toronto, Ontario, Canada; London, England, 1949. 401 pages, illustrations, diagrams, charts, tables, $9^1/_4$ by 6 inches, cloth, $5. Second of a projected 4-volume series of which the author's "Applied Mathematics" was the first, this book covers the physics of circuit elements, including vacuum tubes, and discusses the fundamentals of a-c and d-c circuits. In general, each chapter presents the theory, develops design equations, applies them to practical problems, which are completely worked out, and presents exercises for chapter review.

Library Services

ENGINEERING Societies Library books may be borrowed by mail by AIEE members for a small handling charge. The library also prepares biblographies, maintains search and photostat services, and can provide microfilm copies of any item in its collection. Address inquiries to Ralph H. Phelps, Director, Engineering Societies Library, 29 West 39th Street, New York 18, N. Y.

AUTOMATIC TELEPHONE PRACTICE. By H. E. Hershey. Sixth edition. Technical Publications, Post Office Box 68, Whitewater, Kans., 1949. 256 pages, illustrations, diagrams, charts, tables, $11^{1}/_{4}$ by $8^{1}/_{2}$ inches, fabrikoid, \$6. This book deals in a detailed manner with the principles of the Strowger automatic system of "setting up" telephone connections. Part *A* presents elementary principles for those with no previous experience in telephone work. Part *B*, presupposing a working knowledge of the system, covers more advanced topics and constitutes a historical review. The remaining two parts deal with fundamental circuit elements and with typical circuits. Appendixes describe typical adjustments and certain elementary principles.

ELECTRICAL TECHNOLOGY. By H. Cotton. Sixth edition. Sir Isaac Pitman and Sons, Ltd., London, England, 1949. 600 pages, diagrams, charts, tables, $8^{3}/_{4}$ by $5^{1}/_{2}$ inches, cloth, 18s. Covering the usual topics included in a basic electrical engineering text, this book presents both a-c and d-c theory and applications. Measuring instruments and illumination are also discussed. In this sixth edition the major change is the addition of new material to the chapter dealing with general circuit theory and to the chapter on illumination.

ELECTROMAGNETIC THEORY (Proceedings of Symposia in Applied Mathematics, Volume II). American Mathematical Society, 531 West 116th Street, New York, N. Y., 1950. 91 pages, diagrams, charts, tables, $10^{1}/_{4}$ by 7 inches, cloth, \$3. This volume contains seven papers and ten abstracts of papers presented at the symposium on electromagnetic theory held at the Massachusetts Institute of Technology in 1948. The seven papers discuss: new quantum electrodynamics, electromagnetism, the factorization method, nonlinear electric networks, ray theory versus normal mode theory in wave propagation problems, and systems of Wiener-Hopf integral equations. Most of the papers which are abstracted were published in full elsewhere.

FREQUENCY MODULATED RADAR. By D. G. C. Luck. Radio Corporation of America, RCA Laboratories Division, Princeton, N. J., 1949. 466 pages, illustrations, diagrams, charts, tables, $9^{1}/_{4}$ by 6 inches, cloth, \$4. Originally prepared as a final report to the Navy, this book covers principles and possibilities in a detailed manner. It develops the general principles of distance and speed determination by frequency-modulation radar. Some of the radio apparatus found useful in frequency-modulation radar equipment are described, as are certain indicating and control devices for utilization of frequency-modulation radar data. The kinematics of simple fire-control problems is developed, and equipment used is described. It is assumed the reader is thoroughly familiar with normal techniques of radio engineering and has some familiarity with pulse radar and with servomechanisms.

INDUSTRIAL ELECTRONIC CONTROL. By W. D. Cockrell. Second edition. McGraw-Hill Book Company, New York, N. Y.; Toronto, Ontario, Canada; London, England, 1950. 385 pages, illustrations, diagrams, charts, tables, $8^{1}/_{4}$ by $5^{1}/_{2}$ inches, cloth, \$4. In a practical, nonmathematical treatment, this manual explains the fundamentals of electron-tube operation and shows how it is applied in the basic circuits used in industrial electronic control. In addition to inclusion of recently developed circuits for counting and switching, the revisions to this second edition include a new section on closed-cycle control regulating systems. In this second edition all wiring diagrams have been redrawn to agree with the new American Standards Association Industrial Electronic Symbols.

INTRODUCTION TO INDUSTRIAL METALLURGY. By L. Aitchison. Macdonald and Evans, 8 John Street, Befford Row, London, W. C. 1, England, 1949. 456 pages, diagrams, charts, tables, $8^{3}/_{4}$ by $5^{1}/_{2}$ inches, cloth, 30s. (available in America from the American Agent, Edward W. Sweetman, 1 Broadway, New York 4, N. Y.). This book is intended to provide a complete picture of the structure, organization, operation, and control of a metallurgical plant. Emphasizing executive and management problems, it deals with both simple and complex production setups, supervision, personnel relations, plant layout, incentives, process and quality control, and the evaluation of productivity.

MATHEMATICS DICTIONARY. Edited by G. James and R. C. James. D. Van Nostrand Company, Toronto, Ontario, Canada; New York, N. Y.; London, England, 1949. 432 pages, diagrams, tables, $9^{1}/_{4}$ by 6 inches, cloth, \$7.50. The earlier version of this dictionary covered terms in the range beginning with arithmetic and extending through the calculus. In the new edition basic terms have been added for metric differential geometry, theory of functions of real and complex variables, differential equations, theory of groups and of matrices, point-set topology, analytic mechanics, theory of potential, and statistics. Frequently used formulas appear in the context, and an appendix contains basic mathematical symbols and useful tables.

MATRIX ANALYSIS OF ELECTRIC NETWORKS. By P. Le Corbeiller. Harvard University Press, Cambridge, Mass.; John Wiley and Sons, New York, N. Y., 1950. 112 pages, diagrams, $8^{1}/_{2}$ by $5^{1}/_{2}$ inches, cloth, \$3. The purpose of this book is to present the essentials of the method of network analysis developed by Gabriel Kron in a form that can be understood and used by all electrical engineers. Following a presentation of the essentials of matrix algebra, the method, stripped of all unessential mathematics, is developed and applied.

MECHANICAL WEAR, Proceedings of Conference held June 1948 at Massachusetts Institute of Technology, Cambridge, Mass. Edited by J. T. Burwell, Jr. Published by American Society for Metals, Cleveland, Ohio, January 1950. 387 pages, illustrations, diagrams, charts, tables, $9^{1}/_{4}$ by 6 inches, cloth, \$6.50. Presenting different aspects of the wear phenomenon, this volume contains the papers and principal discussions presented at the Massachusetts Institute of Technology Special Summer Conference on Mechanical Wear held in June 1948. The papers cover laboratory and service experience on wear in internal combustion engines, steam turbines, brake materials, journal bearings, gears, electric brushes, surface plates, and cutting tools. The effect of various factors on wear in any or all of the above types of services is also discussed.

NICKEL ALLOY STEELS. Second edition. International Nickel Company, Development and Research Division, New York, N. Y., 1949, paged in sections, illustrations, diagrams, charts, tables, $9^{1}/_{4}$ by $7^{1}/_{2}$ inches, fabrikoid, gratis, limited distribution. This second edition revises and brings up to date pertinent data on nickel alloy steels. The nine sections deal respectively with applications, wrought steels, cast steels, manufacture and processing, heat treatment, special properties, stainless steels, iron-nickel, and related alloys, and general information. It is published in loose-leaf form, as new data sheets and revisions will be issued as the need arises.

RADIO AMATEUR'S HANDBOOK. By the Staff of American Radio Relay League, West Hartford, Conn., 27th edition, 1950. 605 pages, plus catalogue section, 110 pages, illustrations, diagrams, charts, tables, $9^{1}/_{2}$ by $6^{1}/_{2}$ inches, paper, \$2 in United States (\$2.25 in Canada and United States possessions), \$2.50 elsewhere. The 27th edition of this standard manual of amateur radio communications covers the entire field from basic fundamentals to the latest techniques in single-sideband telephony. Reflecting the changes in technical practices of the past year, the problem of interference with television reception is treated extensively. The chapter on measuring equipment has been expanded. A considerable amount of information on new equipment is incorporated in the chapters covering the very-high and ultrahigh frequencies. The tube tables have been revised to include the newest tubes.

TELEVISION FOR RADIOMEN. By E. M. Noll. Macmillan Company, New York, N. Y., 1949. 595 pages, illustrations, diagrams, charts, tables, $9^{1}/_{2}$ by $6^{1}/_{4}$ inches, cloth, \$7. Written to serve as a television text for practical radiomen and television students, this text explains in practical terms the principles and essential mathematics of the subject. It describes each part of modern television equipment, showing the particular application of theory in the construction and operation of each. Two chapters deal with installation, adjustment, alignment, and trouble shooting. A rather thorough knowledge of radio circuits is assumed.

TERRESTRIAL RADIO WAVES, THEORY OF PROPAGATION. By H. Bremmer. Elsevier Publishing Company, New York, N. Y., Amsterdam, Holland; London, England; Brussels, Belgium; 1949. 343 pages, diagrams, charts, tables, $9^{1}/_{2}$ by $6^{1}/_{2}$ inches, cloth, \$5.50. Mathematical methods are described by which the electromagnetic field of a radio transmitter can be computed, taking into account the curvature of the earth's surface. The first part deals with the theory relating to a homogeneous atmosphere, that is, ground waves. In the second part, the theory is extended for an inhomogeneous atmosphere, that is, skywaves and the reflection phenomena in the lower atmosphere of the ground wave. Special attention is paid to the physical interpretation of the mathematical deductions.

PAMPHLETS • • • • •

The following recently issued pamphlets may be of interest to readers of "Electrical Engineering." All inquiries should be addressed to the issuers.

Employment Outlook for Engineers. A report by the Bureau of Labor Statistics on employment trends and outlook, earnings, and occupational mobility for engineers. 120 pages. Priced at 50 cents, this report is available from the Superintendent of Documents, Government Printing Office, Washington 25, D. C.

Design Manual on Aircraft Electrical Installations. This publication is a design guide on electric system installations for transport aircraft. Although basically prepared for transport category aircraft, most of the features of the manual are also applicable to military aircraft and other types of commercial planes. Available at \$1.75 from the Aircraft Industries Association, 610 Shoreham Building, Washington 5, D. C.

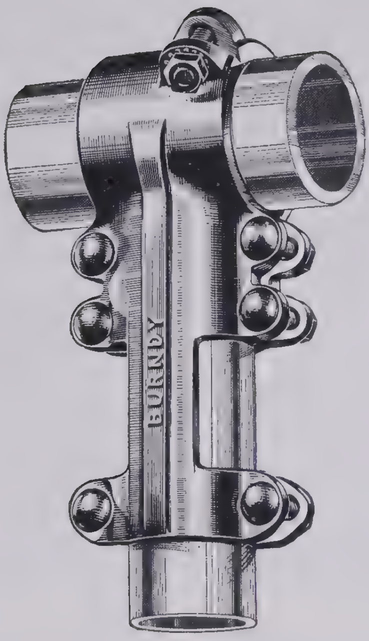
The Geiger-Muller Counter. The nature, construction, and use of the Geiger-Muller counter is concisely presented in a new booklet published by the National Bureau of Standards, circular 490. 25 pages. Illustrated. Priced at 20 cents and available from the Superintendent of Documents, Government Printing Office, Washington 25, D. C.

Lighting for Canneries. Describes the recommended lighting conditions through all operations of the canning process. Copies of this 36-page booklet are available at 50 cents each from the Publications Office, Illuminating Engineering Society, 51 Madison Avenue, New York 10, N. Y.

Bibliography of Technical Reports. 313 technical documents on a variety of subjects are listed in the March issue of "Bibliography of Technical Reports." A limited supply is available for free distribution from the Office of Technical Services, Department of Commerce, Washington 25, D. C.

Residual Stresses in Metals, by Dr. William M. Baldwin, Jr. This 48-page illustrated booklet covers the fundamental differences in the mechanisms by which residual stresses are developed by cold-working operations, by heat treatment, and by casting and welding. Copies can be obtained from the American Society for Testing Materials, 1916 Race Street, Philadelphia 3, Pa., at \$1 each.

Research and Development in Applied Optics and Optical Glass at the National Bureau of Standards, by Irvine C. Gardner and C. H. Hahner. A general account of the Bureau of Standards' broad program of research and development in optics and optical glass since 1901, which has led to the solution of many problems of interest to both Government and private industry. A complete bibliography of 195 publications is included. Available at 15 cents per copy from the Superintendent of Documents, Government Printing Office, Washington 25, D. C.



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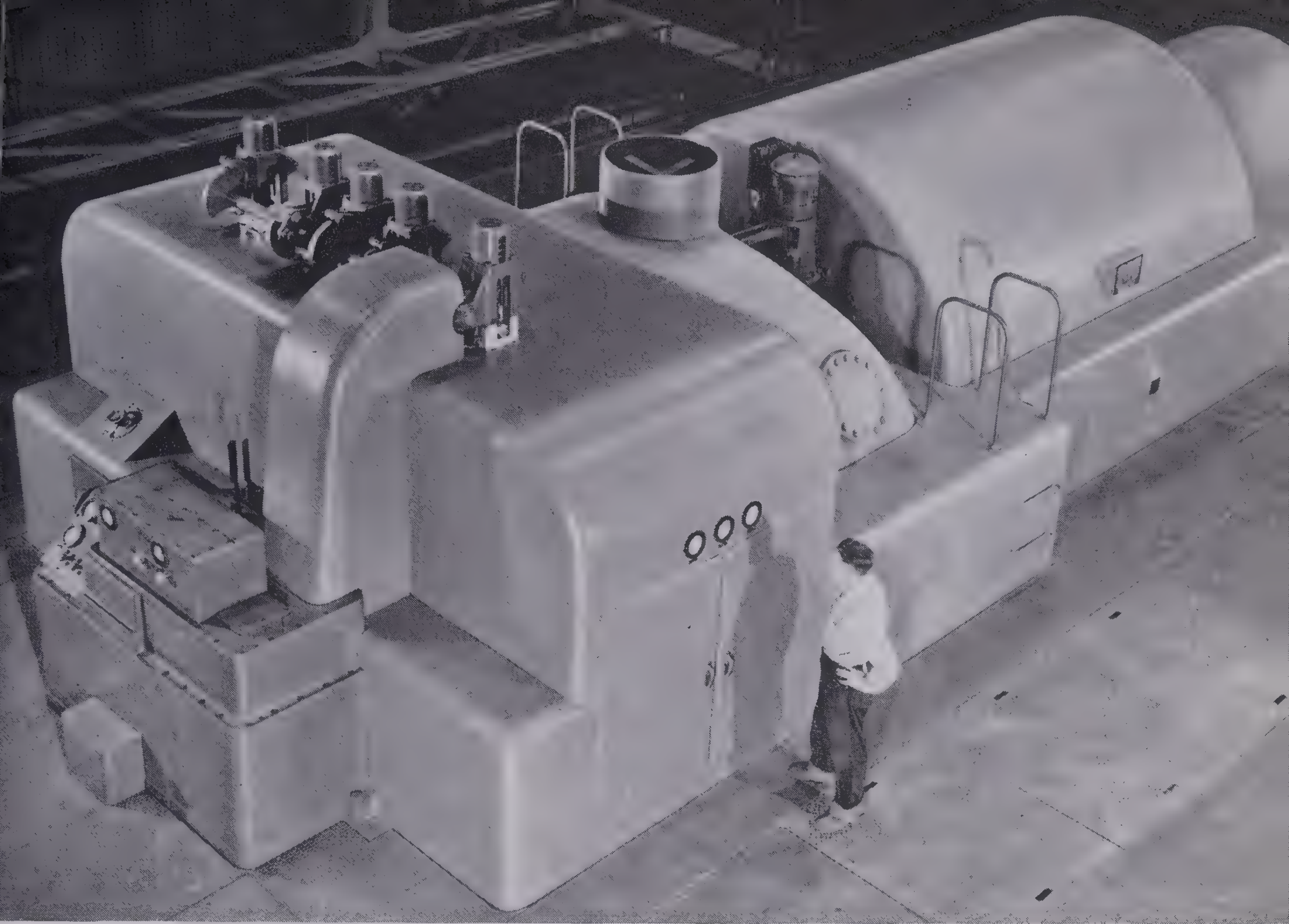

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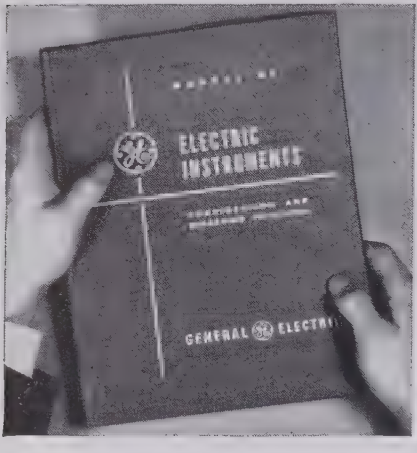

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INDUSTRIAL NOTES ....

Former Allen-Bradley Chief Dies. Gustav O. Wilms, retired Chief Engineer of the Allen-Bradley Company, passed away recently at his home in Sarasota, Fla. Mr. Wilms pioneered many important developments in the control field, chief of which was the modern solenoid switch.

Kribs Treasurer of Moloney Electric. George J. Kribs was elected Treasurer of the Moloney Electric Company recently, succeeding Mr. Thomas O. Moloney, who was made Chairman of the Board. All other officers of the corporation were reelected.

Alcoa News. M. Russell Kambach has been named Advertising Manager for the Aluminum Company of America, and Jay M. Sharp succeeds Mr. Kambach to his former post, as Assistant Advertising Manager. The company has also named A. H. Schmeltz Manager of their newly-established Patent Department; John M. Mitchell Manager of the Export Division; and G. B. D. Peterson head of the Export Division's New York office.

Allis-Chalmers Board of Director's Appointment. Frederick Bohen, President of the Meredith Publishing Company, Des Moines, Iowa, has been elected a member of the board of directors of the Allis-Chalmers Manufacturing Company, Milwaukee, Wis. Mr. Bohen succeeds the late Arthur W. Butler of New York.

General Radio Elects New Director. Charles C. Carey has been elected a Director of the General Radio Company, succeeding Henry S. Shaw, who has retired.

Westinghouse News. R. F. Spangle has been appointed Field Service Supervisor for the Pacific Coast Seattle Division of the Westinghouse Electric Corporation; Henry B. Ahlers has been made assistant to John K. Hodnette, Vice-President and General Manager of the Industrial Products Divisions of the corporation; R. B. Church, Jr., has been named assistant to the Southeastern District Manager; and B. M. Gatling, Jr., has been appointed Central Station Division Manager. Westinghouse has also announced the retirement of Thomas Fuller, former Manager of the company's Southeastern District.

Sylvania Appointments. Sylvania Electric Products, Inc., has announced the following: Arthur L. Chapman has succeeded E. E. Lewis as General Manager of the Colonial Radio and Television Division (Mr. Lewis resigned as Vice-President in charge of that division to return to his industrial management consulting business); George R. Sommers has been appointed Assistant General Sales Manager, Radio Tube Division; James F. Davis has been named District Sales Manager of the New Jersey area; Gabriel V. Bureau has been made Field Engineer for the Equipment Sales Department of the Radio Tube Division; and Robert A. Starek has been appointed Field Engineer for the Radio Tube Division of the company.

Lear Appointment. Lear, Inc., has announced the appointment of R. S. Atkinson as Sales Manager of its Romec Division, located at Elyria, Ohio.

General Electric News. Robert S. Neblett, Assistant General Manager of the General Electric Company's Nucleonics Department, has been appointed Business and Construction Manager of the Knolls Atomic Power Laboratory, and Robert O. Bullard has been appointed to work with Mr. Neblett as Assistant Business and Construction Manager. General Electric has also announced the appointments of D. M. Hood as Manufacturing Engineer of the General Electric Fan Division; F. T. Grothouse and J. L. Knight Assistant Managers of Engineering for the company's Appliance and Merchandise Department; and James H. Alderman, District Representative for the Construction Materials Department. Four appointments to sales positions in the General Electric Commercial Equipment Division are as follows: F. P. Barnes, Sales Manager of Communication Equipment; H. M. Wales, Sales Manager of Marine and Aviation Equipment; L. W. Goostree, Jr., Sales Manager of Communication Equipment; and N. Gada, assistant to the manager of sales.

Ohio Brass Appoints Owens. The Ohio Brass Company has named William B. Owens as District Manager of the territory in the Southeast formerly covered by the late George Willis.

Korrell Made Vice-President and Director of Sales at Soreng. Soreng Manufacturing Corporation has announced the appointment of P. H. Korrell to the position of Vice-President and Director of Sales.

Highland Engineering. The Highland Engineering Company, at Hicksville, N. Y., which was opened last October by William R. Spittal, has announced manufacture of custom built transformers, inductors, rectifiers, and power supplies, made to customer's specific requirements.

New Chief Engineer for Cannon Electric. Roger Bowen, formerly with the United States Signal Corps, has been made Chief Engineer of the Cannon Electric Development Company, in place of D. Frank

(Continued on page 24A)

PRECISION ATTENUATION to 3000 mc!

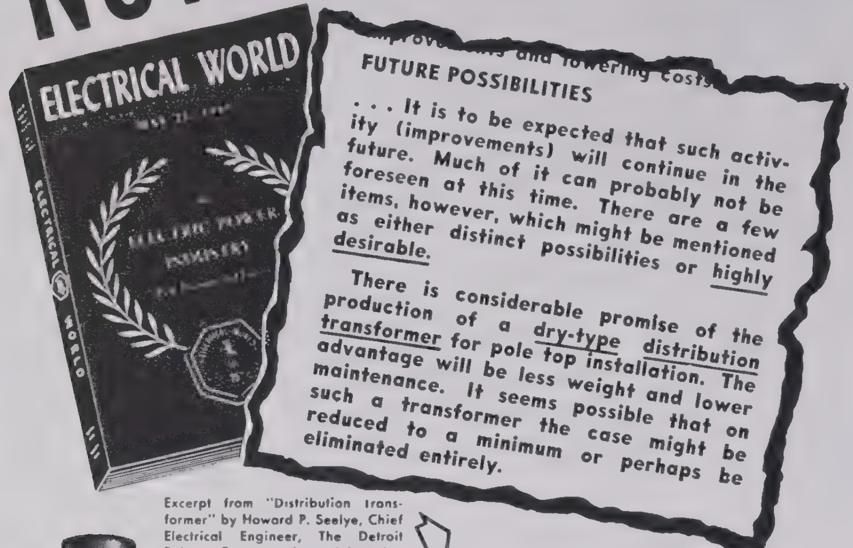
*Patents applied for

- VSWR less than 1.2 at all frequencies to 3000 mc.
- **Turret Attenuator*** featuring **"Pull — Turn — Push"** action with 0, 10, 20, 30, 40, 50 DB steps.
- Accuracy ± .5 DB, no correction charts necessary.
- 50 ohm coaxial circuit. Type N connectors.

Inquiries are invited concerning single pads and turrets having other characteristics

STODDART AIRCRAFT RADIO CO.
6644 SANTA MONICA BLVD., HOLLYWOOD 38, CALIFORNIA
Hillside 9294

NOW! the transformer of the future


ELECTRICAL WORLD
ELECTRIC POWER INDUSTRY

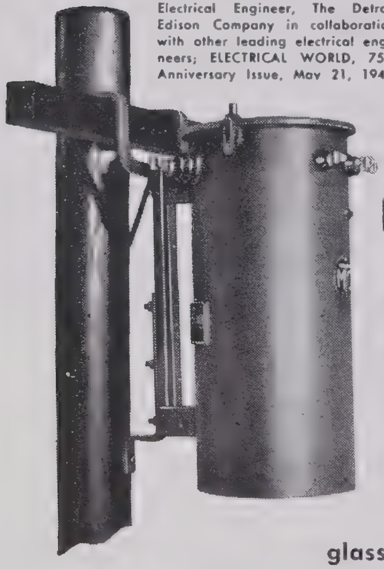
improvements and lowering costs

FUTURE POSSIBILITIES

. . . It is to be expected that such activity (improvements) will continue in the future. Much of it can probably not be foreseen at this time. There are a few items, however, which might be mentioned as either distinct possibilities or highly desirable.

There is considerable promise of the production of a dry-type distribution transformer for pole top installation. The advantage will be less weight and lower maintenance. It seems possible that on such a transformer the case might be reduced to a minimum or perhaps be eliminated entirely.

Excerpt from "Distribution transformer" by Howard P. Seelye, Chief Electrical Engineer, The Detroit Edison Company in collaboration with other leading electrical engineers; ELECTRICAL WORLD, 75th Anniversary Issue, May 21, 1949.



Currently available in sizes to 100 KVA, voltages to 5000 V.

MARCUS

DRY TYPE AIR COOLED DISTRIBUTION TRANSFORMERS

Months before the publication of this excellent article on distribution transformers, Marcus, a pioneer in the field, announced a new line of *all purpose* dry type distribution transformers for indoor or outdoor service.

The complete absence of hazardous oil or toxic liquid affords safety never before realized. Superior Class B and C heatproof insulation, such as fibreglass, mica, porcelain, new Johns-Manville Quinterra, etc., results in overload capacities unobtainable with Class A oil filled units. The entire transformer element is seal protected against oil, acids, moisture, etc., and is housed in a sturdy, scientifically ventilated, weather proof case which conforms with all applicable EEI-NEMA construction standards. This extremely versatile transformer can be used outdoors, pole or platform mounted or indoors at the load center, mounted wherever convenient with no expensive fireproof vault required.

AIR-COOLED TRANSFORMERS EXCLUSIVELY
1 to 2,000 KVA up to 15,000 Volts to meet Individual Requirements
- DISTRIBUTION
- GENERAL PURPOSE
- UNIT SUBSTATION
- PHASE CHANGING
- ELECTRIC FURNACE
- RECTIFIER
- WELDING
- MOTOR STARTING

Write for Bulletin #49-ACO

COMPETITIVE PRICES — GOOD DELIVERIES

MARCUS TRANSFORMERS CONFORM TO THE STANDARDS OF N.E.M.A. AND A.I.E.E.

Representatives in Principal Cities

MARCUS TRANSFORMER CO.
INC.
34 MONTGOMERY STREET
HILLSIDE 5, NEW JERSEY

PIONEERS IN THE FIELD OF AIR-COOLED TRANSFORMERS

AIEE TRANSACTIONS VOLUMES WANTED

A refund is offered for the 1942 and 1947 bound volumes of AIEE TRANSACTIONS. Please mail (parcel post) to the American Institute of Electrical Engineers, 33 West 39th Street, New York 18, N. Y., printing your name and address upon the wrapper. $4.00 plus postage, will be paid for each volume, provided the books are in a saleable condition.

5-50

BACK COPIES WANTED

Copies of the January 1949 issues of ELECTRICAL ENGINEERING. Please mail (parcel post) to American Institute of Electrical Engineers, 33 W. 39th St., New York 18, N. Y., printing your name and address upon the mailing wrapper. Twenty-five cents, plus postage, will be paid for each copy returned.

5-50

UP TO 50,000 MEGOHMS

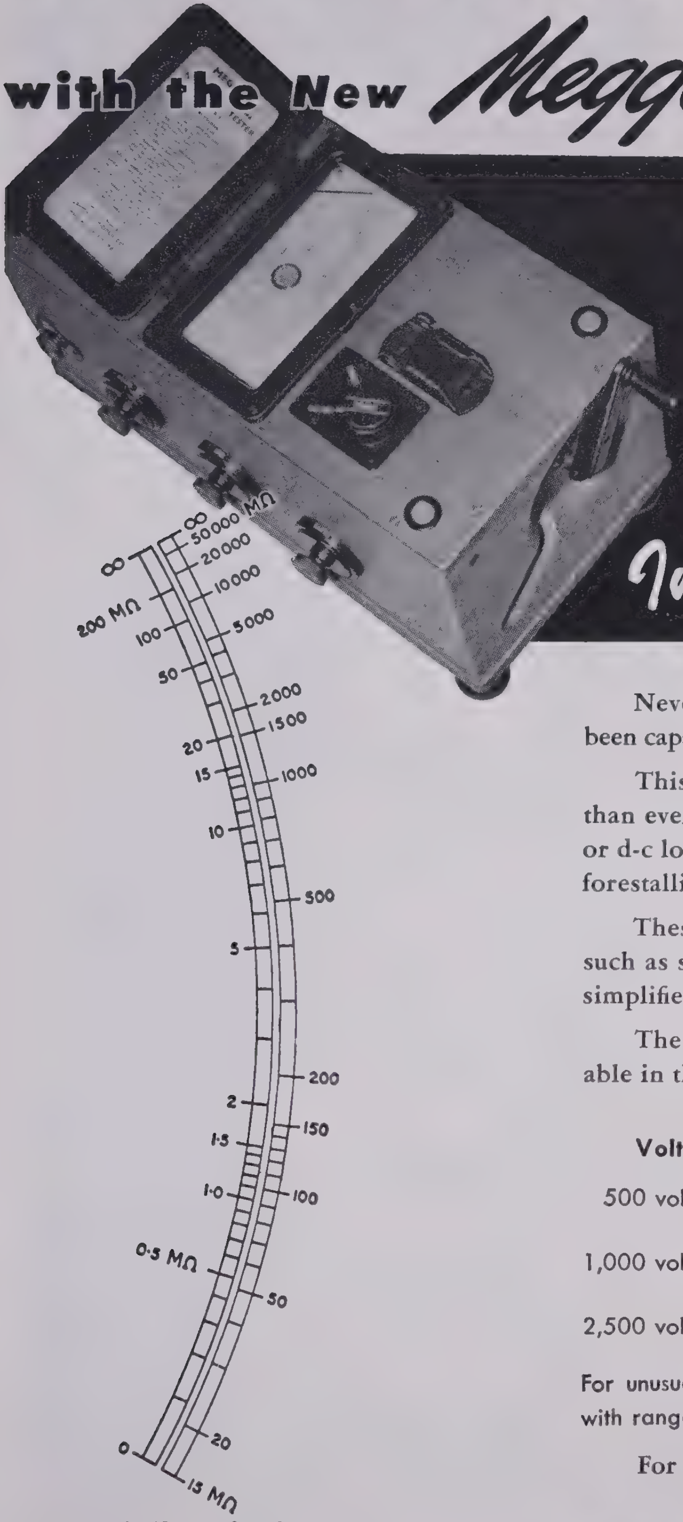
with the New *Megger*® Insulation Tester

New **Higher ranges**

Wider ranges

Longer scales

Improved **Mechanical Features**



Facsimile scale of 2,500-volt instrument

Never before has the direct-indicating cross-coil ohmmeter been capable of measuring such high values of insulation resistance!

This accomplishment comes at a time when more attention than ever is being focused by engineers on insulation resistance or d-c loss measurements as a practical non-destructive means of forestalling breakdown in electrical equipment.

These new sets also include several important improvements, such as static shielding, improved hand-drive mechanism, and a simplified design for motor-drive with better voltage stabilization.

The new line of MEGGER Insulation Testers is now available in the following ranges:

Volts	Inner Scale Megohms	Outer Scale Megohms
500 volts d-c	0 to 50	3 to 10,000
1,000 volts d-c	0 to 100	6 to 20,000
2,500 volts d-c	0 to 200	15 to 50,000

For unusual requirements, a special 5,000-volt instrument is available with range up to 100,000 megohms.

For description and prices, *write for Bulletin 21-20EE.*

JAMES G. BIDDLE CO.
Electrical & Scientific Instruments
1316 ARCH STREET, PHILADELPHIA 7, PA.

Megger® INSULATION TESTERS • GROUND TESTERS • OHMMETERS

Gibsiloy

COPPER TUNGSTEN ELECTRICAL CONTACTS

—cost less than Gibsiloy silver refractory materials and serve equally well in many applications

GIBSILOY UW6 copper tungsten electrical contacts are noteworthy for their ability to rupture very heavy currents with minimum erosion. They also exhibit outstanding resistance to galling and wear when a high contact force, associated with a wiping action, is part of the operating conditions.

Typical applications for **GIBSILOY UW6** copper tungsten are:

Air Circuit Breaker Arcing Tips
Air Circuit Breaker Intermediate Contacts
Air Circuit Breaker Arc Runners
Oil Circuit Breaker Arcing Tips
Oil Circuit Breaker Current Carrying Contacts
Oil Immersed Contactor Contacts
Oil Immersed Switches
Oil Immersed Tap Changer Contacts

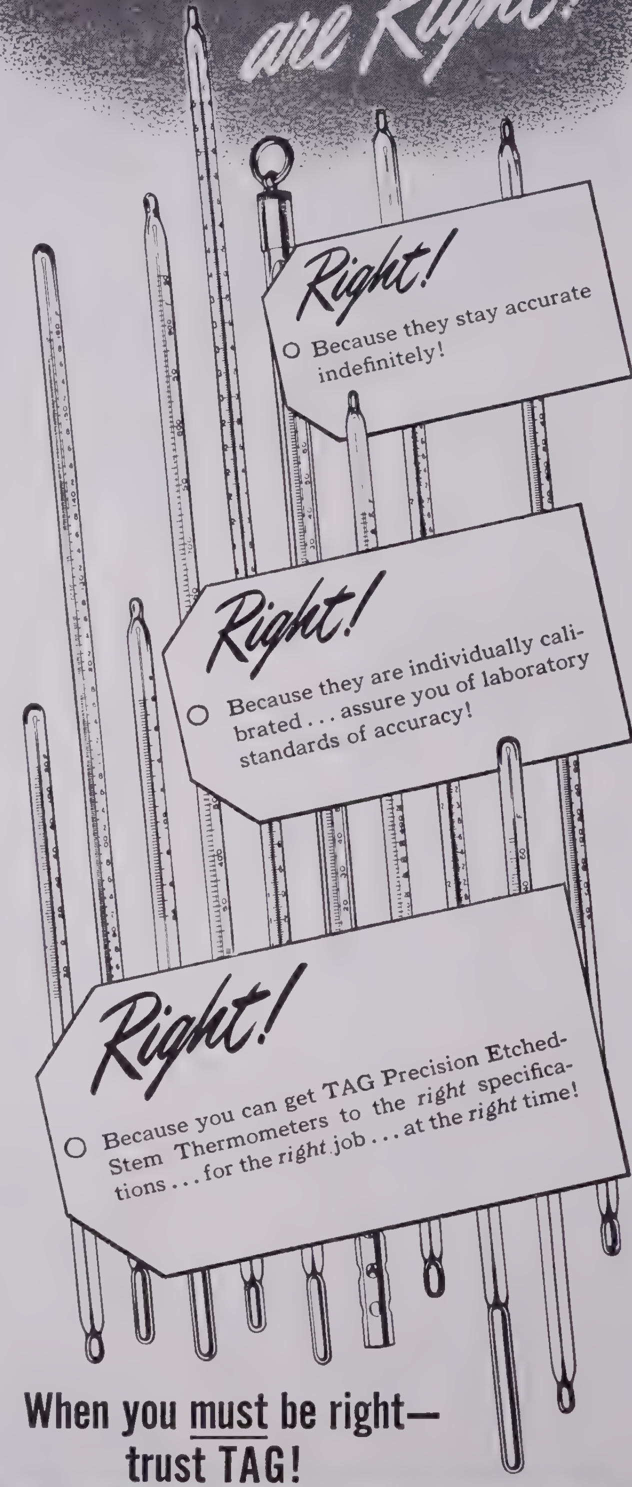
GIBSILOY UW6 copper tungsten is the least expensive of the refractory contact materials. The lower cost of copper tungsten is an important advantage when the electrical and mechanical conditions of the application do not require one of the more expensive materials.

GIBSILOY refractory contacts include silver tungsten and silver molybdenum as well as copper tungsten. Our engineers will gladly recommend the type of Gibson electrical contact material best suited to your application. Write for our recommendation on your contact application problem.

Gibson Electric Company furnishes electrical contacts, as well as complete contact assemblies.

Gibsiloy ELECTRICAL CONTACTS
Manufactured by
GIBSON ELECTRIC COMPANY
8348 Frankstown Ave., Pittsburgh 21, Pa.

TAG precision etched-stem THERMOMETERS *are Right!*



Right!
○ Because they stay accurate indefinitely!

Right!
○ Because they are individually calibrated . . . assure you of laboratory standards of accuracy!

Right!
○ Because you can get TAG Precision Etched-Stem Thermometers to the *right* specifications . . . for the *right* job . . . at the *right* time!

When you must be right—trust TAG!

WESTON ELECTRICAL INSTRUMENT CORPORATION
TAG
Manufacturers of Tagliabue and Weston Instruments
614 Frelinghuysen Avenue, Newark 5, N. J.

ANHYDREX INSULATION

+ NEOPRENE JACKET

= 5-POINT PROTECTION for UNDERGROUND NETWORK CABLES

Anhydrex insulation. Neoprene jacket. Here's a combination that's hard to beat for all-around protection against the hazards that menace underground network cables.

It's exclusive in Simplex-ANHYDREX Cables, and it is their assurance to you of the always-reliable performance that network service demands. More than that, the Anhydrex-Neoprene team keeps down weight and diameter, provides excellent flexibility, does away with the need for duct lubricants, and facilitates jointing, tapping, and terminating, all of which add up to low-cost installation and maintenance.

Check the advantages listed here. See if they don't point to the trouble-free operation you're looking for. And if you would like more-complete information, including specification data, about ANHYDREX Underground Cables, just fill in and return the coupon below.

1. **Moisture Resistance**

   Rigid laboratory testing proves that Anhydrex insulation will not absorb harmful quantities of water. Throughout many years of service in underground and submarine installations no ANHYDREX Cable has ever failed due to water absorption.

2. **Resistance to the Acids, Alkalies, and Corrosive Chemicals Prevalent in Underground Ducts**

3. **Protection Against Oil, Heat and Flame**

   The neoprene jacket will not support combustion and it effectively resists deterioration by oil and heat.

4. **Elimination of Crystallization and Corrosion**

   Needing no outer metallic coverings, ANHYDREX Cables are not subject to electrolysis nor harmed by vibration, stray or secondary currents.

5. **Resistance to Abrasion and Rough Handling**

   The neoprene jacket is unexcelled for toughness; will withstand even more abuse than the best natural rubber compounds.

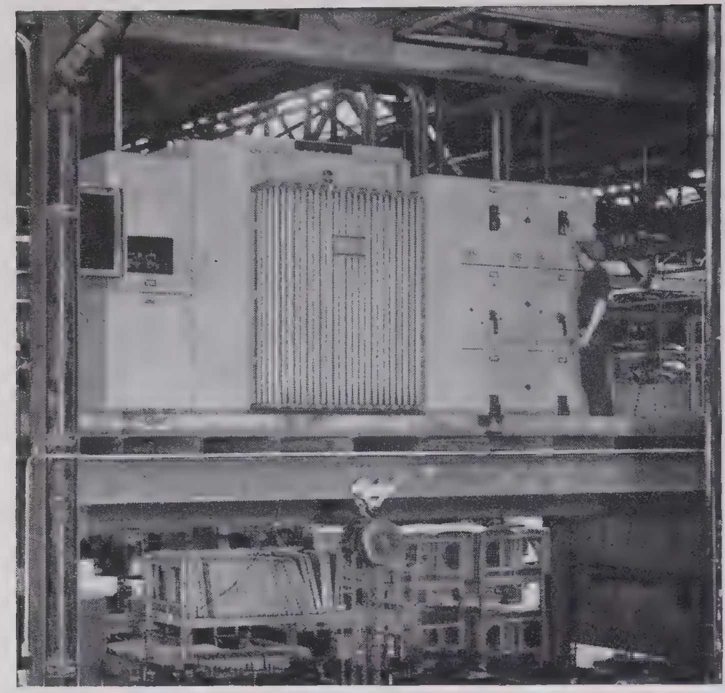
Simplex
WIRES & CABLES

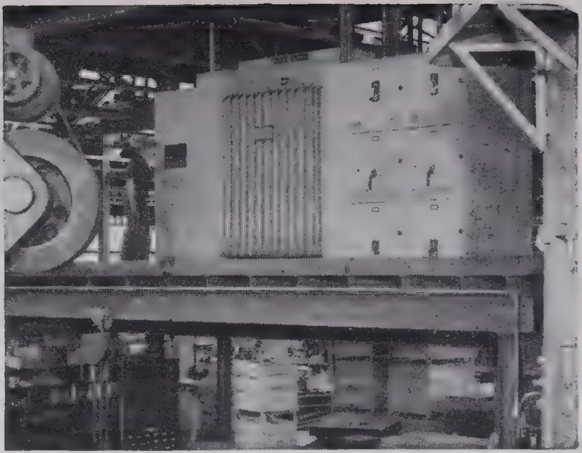
SIMPLEX WIRE & CABLE CO.
79 Sidney St., Cambridge 39, Mass.

SIMPLEX WIRE & CABLE CO.
79 SIDNEY ST., CAMBRIDGE 39, MASS.

GENTLEMEN: PLEASE SEND A COPY OF CATALOG 1013 TO:

NAME________________TITLE________
COMPANY________________________
STREET________________________
CITY________________STATE________

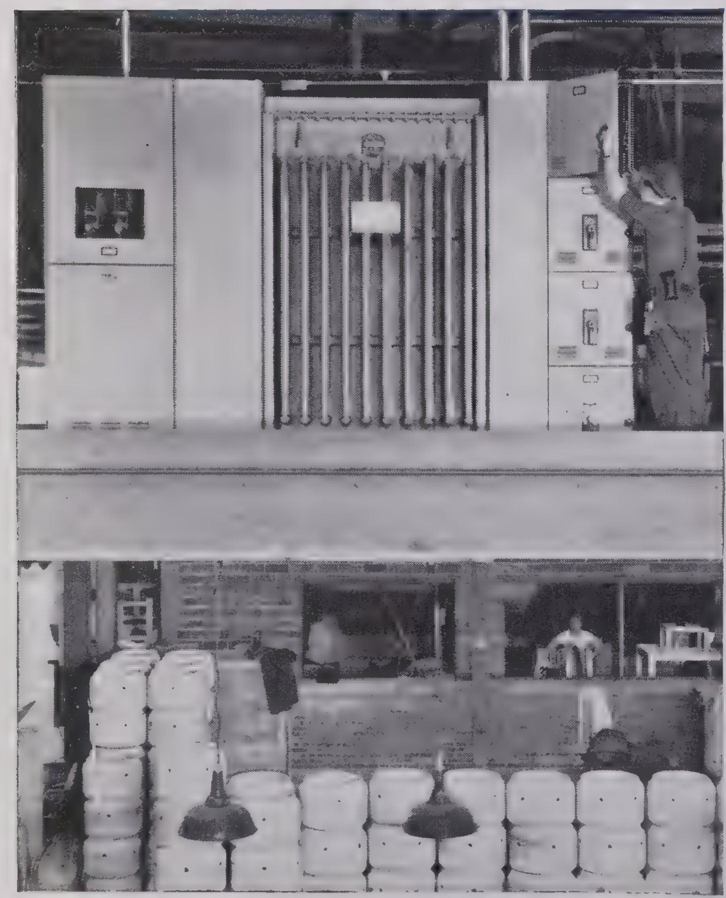




ALL UNIT SUBSTATIONS MOUNTED ON PLATFORMS TO SAVE FLOOR SPACE

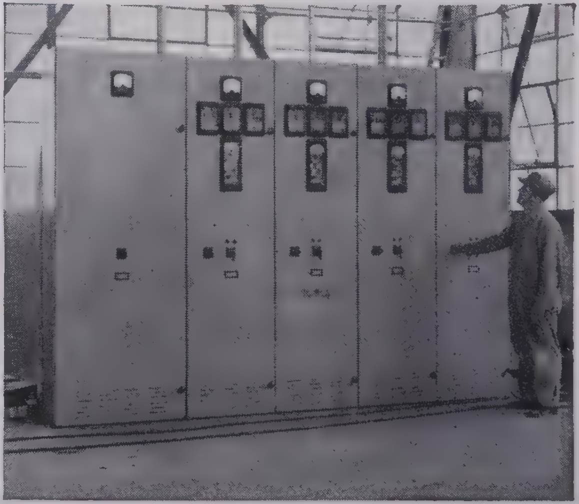
Two views of General Electric 1000-kva load-center unit substation at new Maytag plant. Valuable manufacturing space is saved by locating units on platforms under the roof, right over the center of the load area. Air switch on primary is easy to operate, contacts are easy to see. Air circuit breakers on secondary are of the drawout type, easily removable for inspection and maintenance. Note entire load center is metal enclosed, thus offering operating safety to personnel.

LOAD-CENTER UNIT SUBSTATIONS

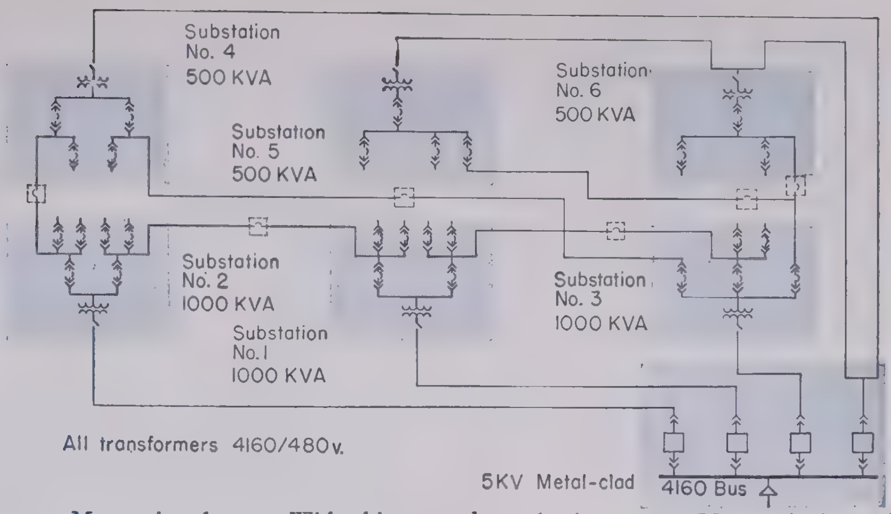


◀ Unit substation No. 5, rated 500 kva. Air circuit breaker for future circuit can be inserted in empty upper housing. Drawout breakers are G-E Type AK-1 with 25,000 ampere interrupting rating—plenty of "IC" (Interrupting Capacity) to handle all short circuits. Contacts of 5 kv air switch are clearly visible through window, another safety feature of G-E substations.

G-E 5-kv metal-clad switchgear handles 4160 volts incoming power, distributes it to six load-center unit substations where it is stepped down to 480 volts for utilization. Metal-clad switchgear is neat in appearance, saving in space, and offers safety to operating personnel. Additional sections can be added for future expansion with a minimum of bother and expense.



CONTINUOUS POWER ASSURED MAYTAG BY SECONDARY-SELECTIVE DISTRIBUTION SYSTEM


Substation No. 4 500 KVA
Substation No. 6 500 KVA
Substation No. 5 500 KVA
Substation No. 2 1000 KVA
Substation No. 3 1000 KVA
Substation No. 1 1000 KVA
All transformers 4160/480v.
5KV Metal-clad
4160 Bus

This secondary-selective system at the new Maytag installation uses General Electric metal-clad switchgear to handle the incoming 4160 volts through four magne-blast power circuit breakers. Feeders distribute the 4160-volt power to six G-E load-center unit susbstations throughout the building where the high-voltage is stepped down to 480 volts for utilization—right at the center of the load area. This eliminates long, costly secondary feeders. Air switches on the primary of all load centers are rated 5 kv. Key interlocks give operating safety to personnel by preventing breaking of the load current with the air switch, or paralleling transformers.

With this secondary-selective system Maytag is insured against a power shutdown in case of failure of any one transformer or its primary feeder cable. If trouble occurs the normally open tie breaker is closed, thus providing an alternate source of power that permits the plant to operate at slightly reduced capacity.

The Maytag installation is a complete General Electric project—one source of responsibility plus the very best in coordinated planning, engineering, manufacturing, and service facilities to give maximum savings and efficiency to the customer.

HELP SPEED PRODUCTION AT THE NEW *Maytag* PLANT AT NEWTON, IOWA

ONLY G-E LOAD CENTERS GIVE YOU THESE FEATURES . . . .

SELECTED STANDARD ratings have been introduced by General Electric to bring you load centers on 20 per cent shorter shipments. The most popular are—

Low voltage	480 △ or Y, 208Y/120 volts
High voltage	2.4, 4.16, 4.8, 12, 13.2, 13.8 kv, delta
Kva ratings	300, 500, 750, 1000, 1500, 2000

Certain other *selected standard* load centers are available. Contact your G-E sales representative for further information.

NEAT APPEARANCE . . . Note the smooth, integrated appearance of these G-E unit substations . . . no more gawky, "old-type" stovepipe connections between transformer and switchgear.

SAVE TIME by eliminating weeks spent over drawing boards detailing individual items. G-E factory-assembled unit substations are quickly and easily installed with lower material and labor costs than required for "piece-meal," makeshift affairs. No last minute "alterations" with hacksaws and cold chisels to make them fit.

INVESTIGATE TODAY how General Electric unit substations can be used in your plant for efficient, flexible power distribution. Contact your G-E sales representative for further information, and write today for the helpful bulletins listed below. *Apparatus Department, General Electric Company, Schenectady 5, New York.*

GEA-3592	Load-center Unit Substations
GEA-3758	Load-center Power Distribution
GEA-3083	Metal-clad Switchgear
GEA-4057	Interlocked-armor Cable for Primary Circuits
GEA-4352	Flamenol Cable for Secondary Circuits

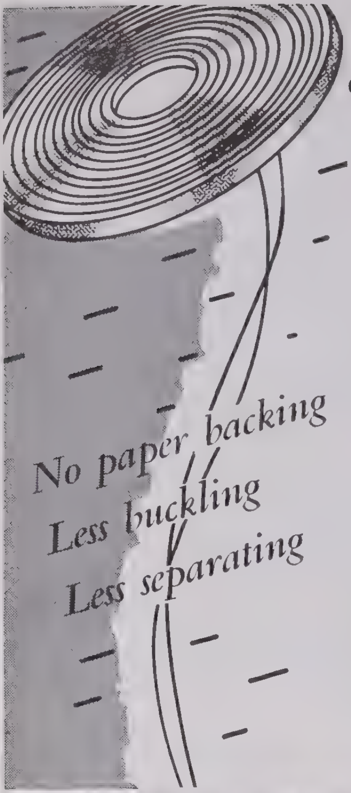
"For our new plant that manufactures Maytag automatic washers, we wanted the very best in power distribution systems. That's why we chose a secondary-selective system using General Electric load-center unit substations. We found that a system such as this would be more economical than any other type. Even though the initial cost was slightly higher than a simple radial system, the fact that we were assured of continuous power for our manufacturing facilities, even though a transformer or feeder cable should drop out, meant that we would save time and money in the long run. We also chose a load-center system because we can easily expand it to take care of any increase in our manufacturing facilities. We also bought 'standard' unit substations because we discovered they would do the job just as well as 'specials'—and at far less cost—and because we could get better delivery. After the units arrived they were installed on the platforms and were operating in a very short time. And dealing with one organization saved us time and money because we could get the engineering, equipment, and service all from one reliable source."

L. C. McAnly, Sr., Manager of Manufacturing,
The Maytag Co., Newton, Iowa

Be sure to see the "More Power to America" full-color sound slide-film "Modern Industrial Power Distribution." Ask your G-E sales representative to arrange a showing for your organization.

GENERAL ELECTRIC

321-66



.0035" THIN

NATIONAL
MICA-GLAS
INSULATION

INSULATING TAPE

If you've had trouble applying insulating tapes of the usual construction—mica sandwiched between glass cloth and paper, and of the usual thickness, .005" or more—just try *this* tape.

On turns of small radius it doesn't buckle nearly as much, because it's backed one side only. Its premium mica is hand laid and bonded so completely to the glass cloth it holds tight — runs through winding machines like a dream.

Supplied with a silicone varnish for extra-high temperatures, standard varnish for the usual Class B use. Available with single layer of mica in .0035" thickness, double layer mica, .005"; both thicknesses are made in widths of half, three-quarter and one inch.

Send for a sample. Inspect it. Try it. It's the answer to a lot of problems. And don't forget—whatever your electrical insulation needs, National has it, ready for quick shipment—and it's *good*.

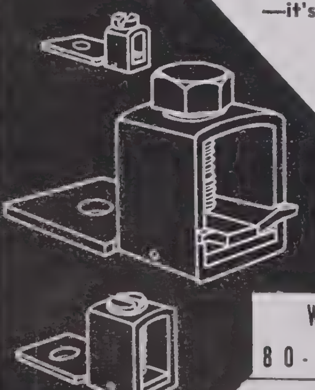
NATIONAL ELECTRIC COIL COMPANY
COLUMBUS 16, OHIO, U. S. A.
ELECTRICAL ENGINEERS: MAKERS OF ELECTRICAL COILS AND INSULATION—
REDESIGNING AND REPAIRING OF ROTATING ELECTRICAL MACHINES
TRADE MARK

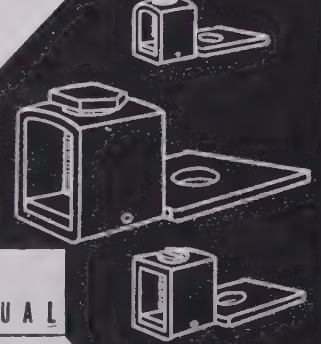
ILSCO

XT SOLDERLESS LUGS

Here's a neat lug that will fit in almost anywhere. It's made of pure electrolytic copper—it's smooth—it's uniform—it really does a job.

Underwriters tested.





WRITE FOR
80-PAGE MANUAL

LOW HEAT RISE
ASSURES ALMOST
50% COOLER
OPERATION

For 6 wire sizes from #14 to 500,000 cm.

ILSCO COPPER TUBE & PRODUCTS, INC.
5743 Mariemont Ave.
CINCINNATI 27, OHIO

(Continued from page 16A)

Jackson, who has been Acting Chief Engineer since the death of Edward Neifing in 1947. Mr. Jackson will continue in the engineering department as chief assistant to Mr. Bowen.

RCA International Appointment. Walter S. Bopp has been appointed Manager of Radio and Appliance Sales for the Radio Corporation of America's International Division.

New Kearney Executives. The James R. Kearney Corporation has announced the elections of F. W. Kearney to the office of Executive Vice-President and Director of Sales; and C. W. Gossett to the office of Vice-President. The company also announced the appointment of J. D. Hoffman, Vice-President, to the post of Chief Engineer.

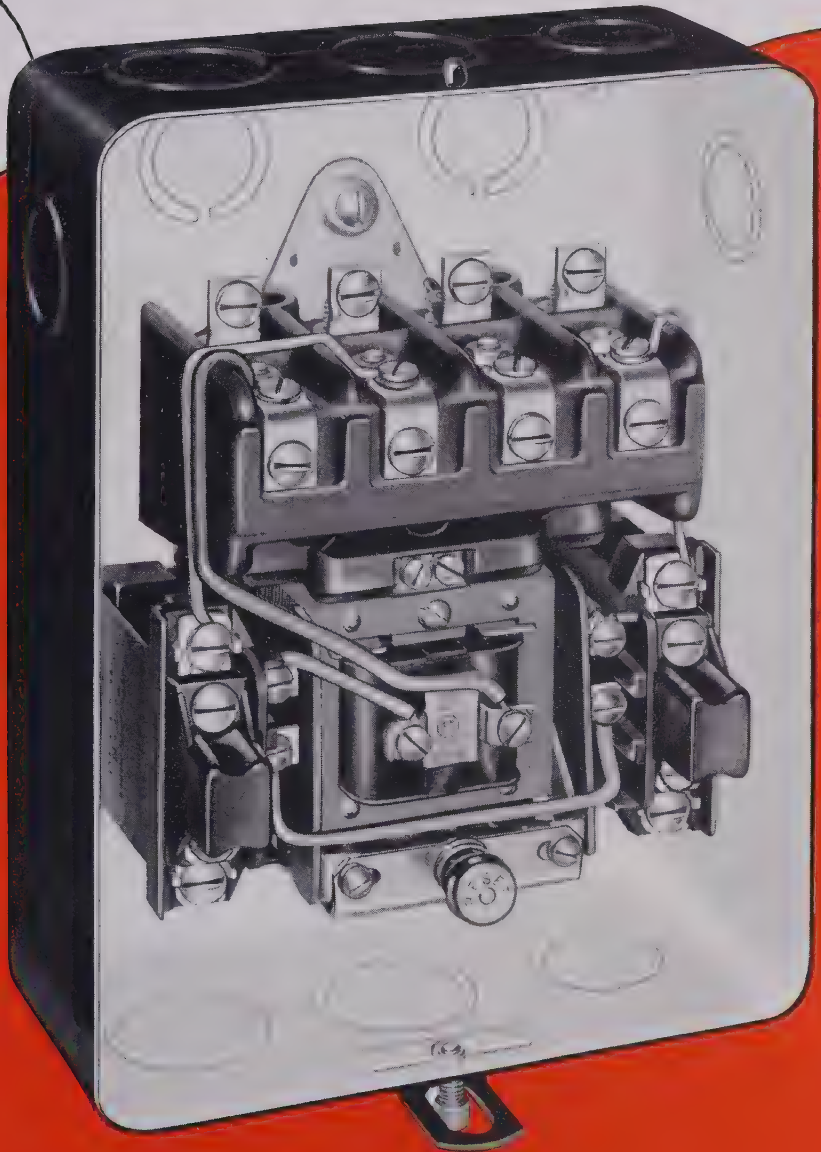
NEW PRODUCTS • •

Cable Fault Locator. The James G. Biddle Company, 1316 Arch Street, Philadelphia 7, Pa., has introduced an impulse cable fault locator and d-c proof tester. The high-voltage d-c impulse transmitter with pickup coil and pointer indicating detector comprising this cable fault locater were designed primarily for locating faults on lead-covered cable installed in ducts. The equipment has applications also on aerial and buried cable. In operation the set is essentially independent of the type of fault or its apparent resistance, and depends only on the impulse voltage required to break down the fault. One set, the model *2-2* fault locator, is rated up to 20 kv with a discharge capacitance of 2.5 microfarads, for use on all cables up to 15 kv and higher. The set requires only about 500 watts to operate for a 115-volt source of high-voltage direct current for proof testing on all types of electric equipment. Bulletin *65-7*, which may be obtained from the company upon written request, contains complete information on this and other fault locator sets.

Demonstration Amplifier. Vickers Electric Division of Vickers, Inc., has designed a self-saturating magnetic amplifier demonstration unit for educational purposes in schools and industry. The new demonstration amplifier is arranged so that all basic single-phase self-saturating circuits may be studied. By arrangement of the external connections either d-c or a-c output is available and either d-c or a-c control power may be used. Reference material and bulletins included with each unit give the wiring diagrams of several control circuits in which this magnetic amplifier may be used, as well as a series of laboratory experiments arranged to help the student determine magnetic amplifier static characteristics, internal impedance and optimum load, dynamic characteristics, and types of

(Continued on page 30A)

> Imitation is the sincerest of flattery
>
> Charles C. Colton



WHY...

do so many starters

look like

Allen-Bradley

Solenoid Starter

- It is no coincidence that most starters, today, look so much like the Allen-Bradley solenoid starter.

There was a time when they did look different. That was before Allen-Bradley brought out the Bulletin 709, Size 1, solenoid starter. It embodied revolutionary features which, today, are established as standard for modern motor controls. That explains why many other starters now resemble Allen-Bradley. But, for simplicity and dependability, Allen-Bradley starters have not been surpassed.

You can reap the benefits of this design leadership by specifying Allen-Bradley motor controls.

ALLEN-BRADLEY CO.
1316 S. Second St., Milwaukee 4, Wis.

ALLEN-BRADLEY

THE MOST IMITATED MOTOR STARTER

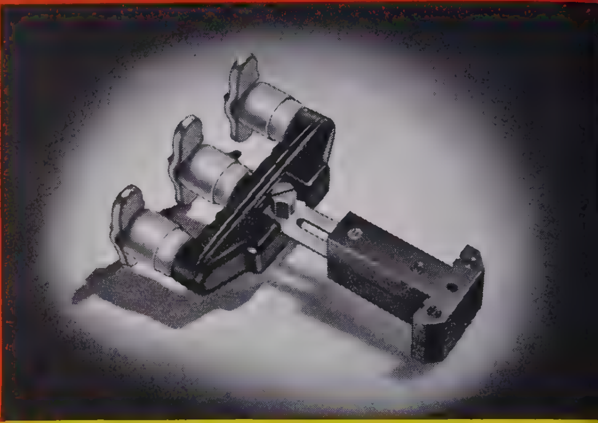
QUALITY

A-B
Quality

350RM

SIMPLICITY—

Only One Moving Part

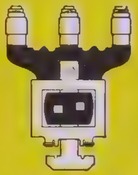


The Key to the Leadership Position of Allen-Bradley Solenoid Starters—Bulletin 709 starters are trouble free because they have no pivots, pins, bearings, intricate linkages, or flexible shunts. Obviously, the more parts . . . the more chances for trouble.

Simplicity of design is the first requirement of a dependable starter. Enjoy this advantage in your motor controls by specifying Allen-Bradley.

1

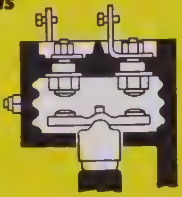
To eliminate trouble-making pins, pivots, etc., you need *Simple Solenoid Action*



The insulating cross bar, carrying the moving contacts of the Allen-Bradley starter, are mounted right on the solenoid plunger. No linkages . . . no pivots or pins.

2

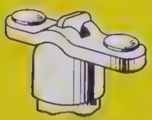
To get small size and to permit close mounting, you need *Enclosed Arc Hoods*



The solenoid construction, with its straight up and down motion and enclosed contacts, is extremely compact. Units can be mounted close together on panels or in machine bases.

3

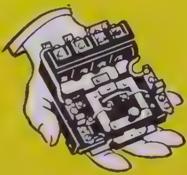
To eliminate contact maintenance, you need *Silver Alloy Contacts*



The patented silver alloy contacts, pioneered by Allen-Bradley on Bulletin 709 solenoid starters, have made contact maintenance, such as filing, cleaning, and dressing, unnecessary.

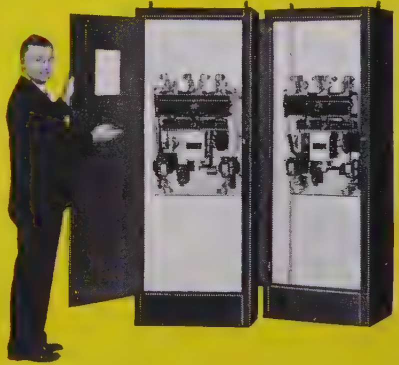
4

To make panel mounting easy, you need *Unit Construction*



Allen-Bradley also pioneered the self-insulated starter mounted on a metal back plate. Bulletin 709 solenoid starters can be grouped closely on control panels of all types.

Bulletin 709 solenoid starters in Sizes 0 to 5, inclusive, for motors up to 100 hp, 220 v; 200 hp, 440-550-600 v.



Bulletin 709 solenoid starters, in Sizes 6 and 7, for motors up to 300 hp, 220 v; 600 hp, 440-550-600 v.

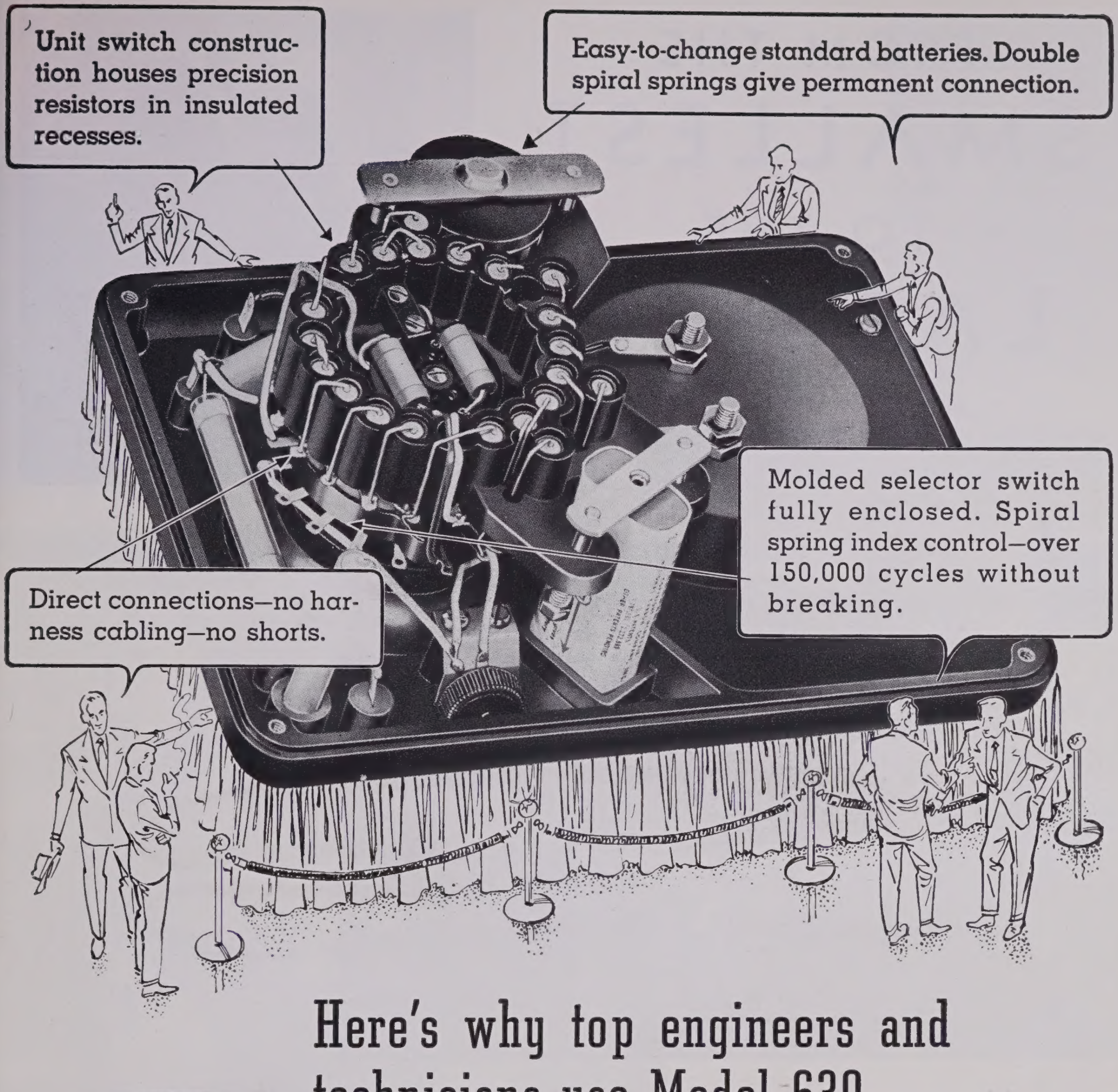
Ample space is provided for the heavy conductors to line and motor terminals. Allen-Bradley starters are available in enclosures for every service . . . indoor or outdoor.

ALLEN-BRADLEY

SOLENOID MOTOR CONTROL

A-B Quality

350R


Unit switch construction houses precision resistors in insulated recesses.
Easy-to-change standard batteries. Double spiral springs give permanent connection.
Molded selector switch fully enclosed. Spiral spring index control—over 150,000 cycles without breaking.
Direct connections—no harness cabling—no shorts.

Here's why top engineers and technicians use Model 630

Features like those shown above are what make this popular V.O.M. so outstandingly dependable in the field. The enclosed switch, for instance, keeps the silvered contacts *permanently clean.* That's rugged construction that means stronger performance, longer life. And tests show that the spiral spring index control, after more than 150,000 cycles of switch rotation, has no disruption or appreciable wear! Investigate this history-making Volt-Ohm-Mil-Ammeter today: 33 ranges, large 5½" meter.

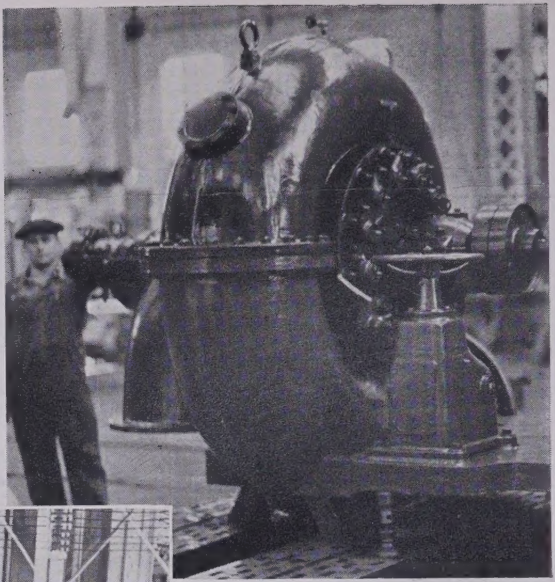
ONLY
$37.50
AT YOUR DISTRIBUTOR

FOR THE MAN WHO TAKES PRIDE IN HIS WORK

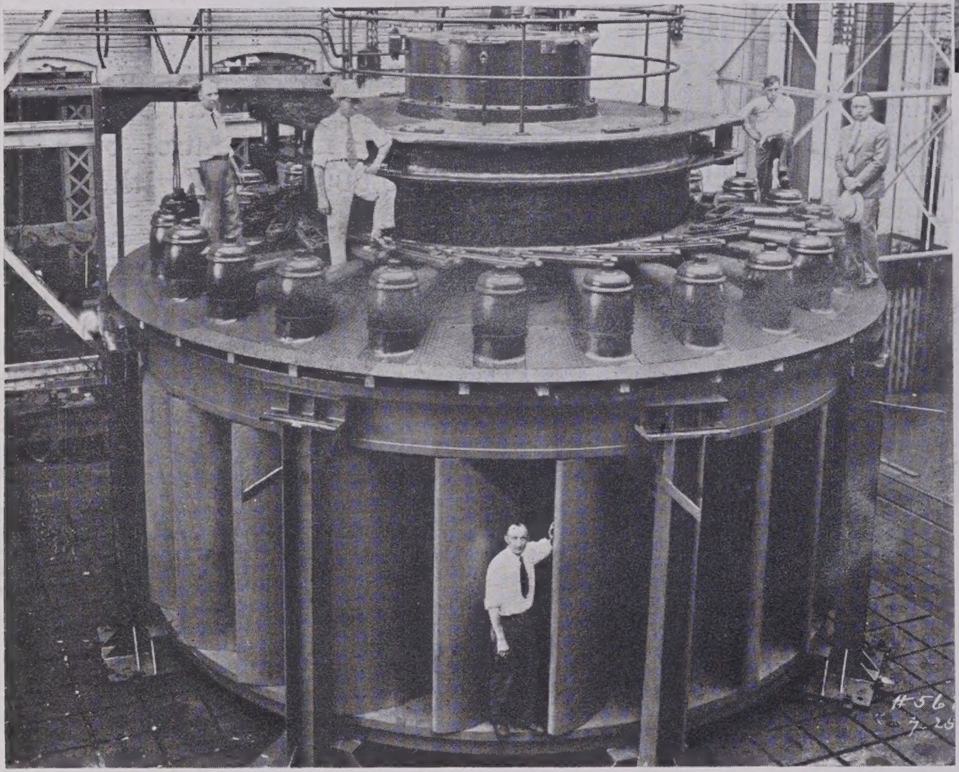
Triplett

TRIPLETT ELECTRICAL INSTRUMENT COMPANY · BLUFFTON, OHIO, U.S.A.

FROM THE SMALLEST TO THE LARGEST



500 Horsepower—
83-foot Head



57,000 Horsepower—
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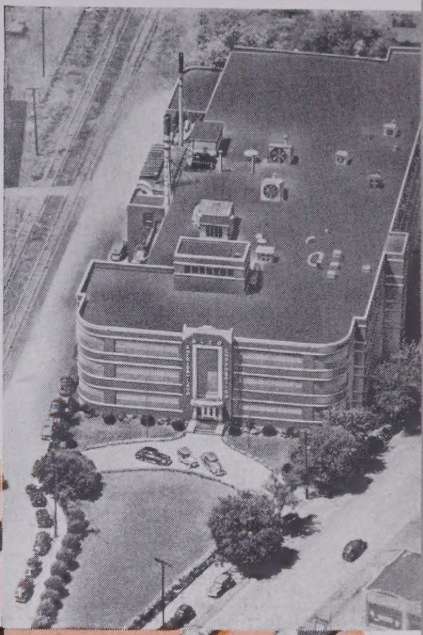

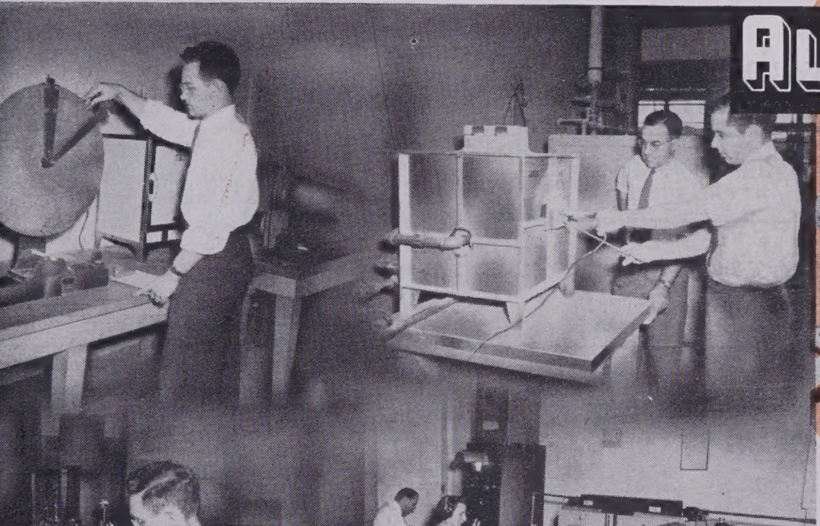

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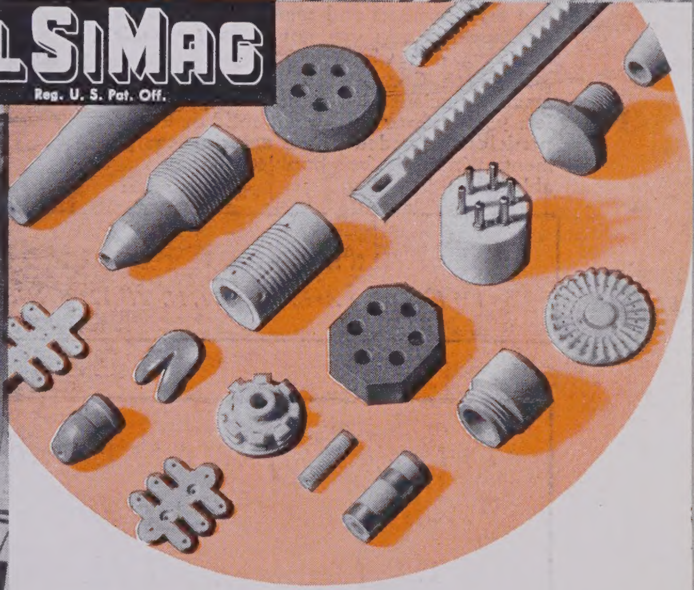

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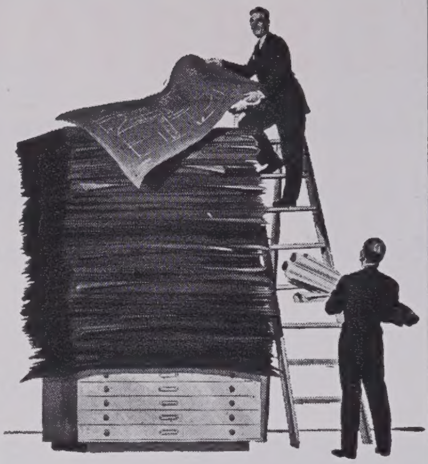

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(*Continued from page 24A*)

control current. Full information is available from the Vickers Electric Division at 1815 Locust Street, St. Louis 3, Mo.

Pocket Drafting Machine. Loomis Industries, 516 Park Way, Piedmont, Calif., has introduced a pocket-portable drafting machine, "Paraline," which measures $10^{1}/_{4}$ inches by $3^{3}/_{16}$ inches. The instrument is constructed of a sturdy transparent section with precision-machined metal moving parts, and requires no clamps or board mountings to remain in alignment. The combination of a 1/32-inch scale and protractor design with moving parts makes Paraline useful as a T-square, parallel rules, triangle, or drafting machine without any adjustments or additional parts. Angles and tangents can be projected by aligning the transparent protractor anywhere along a base line and rolling the instrument until the straight edge intersects the base line at the point at which the angle is to be drawn. The price of the instrument is $4.95. Further details may be obtained from the company.

G-E Developments. A new "trigger-start" ballast for instant starting operation of residential fluorescent lighting has been announced by General Electric's Specialty Transformer and Ballast Division. The new ballasts are designed to operate the standard 20-watt fluorescent lamps and the standard 32-watt circline fluorescent lamps. Starters are not required, and lamp starting is instantaneous, due to cathode heater windings which heat the cathodes to the point where the open circuit voltage of the ballast is sufficient to strike the arc.

Another development at General Electric is a 3-phase automatic recloser, designated type *FR-3*, with maximum service ratings of 100 amperes, 15,000 volts. The new unit extends the advantages of the General Electric *FR-1* single-phase recloser to 3-phase operation. Primarily designed for rural distribution systems, the *FR-3* has a short-circuit interrupting capacity of 3,000 amperes. Construction combines three *FR-1* single-phase reclosers in a single unit. Eliminating the hazard of burning out 3-phase loads by having only one-phase lockout, the new units employ a common linkage that assures positive operation in locking out all three phases whenever a permanent fault occurs. However, the three units operate as single-phase reclosers whenever an intermittent fault occurs.

Additional information on the "trigger start" ballast is contained in bulletin *GEA-5473;* on the *FR-3* 3-phase recloser in bulletin *GEA-5466;* both are available from the General Electric Company at Schenectady 5, N. Y.

Moistureproof Glass Electrodes. A new series of moistureproof glass electrodes has been developed for Leeds and Northrup pH electrode assemblies of the pyrex glass and enameled cast iron types. To assure high insulation and low electrical leakage, electrode lead wires are permanently attached

(*Continued on page 40A*)